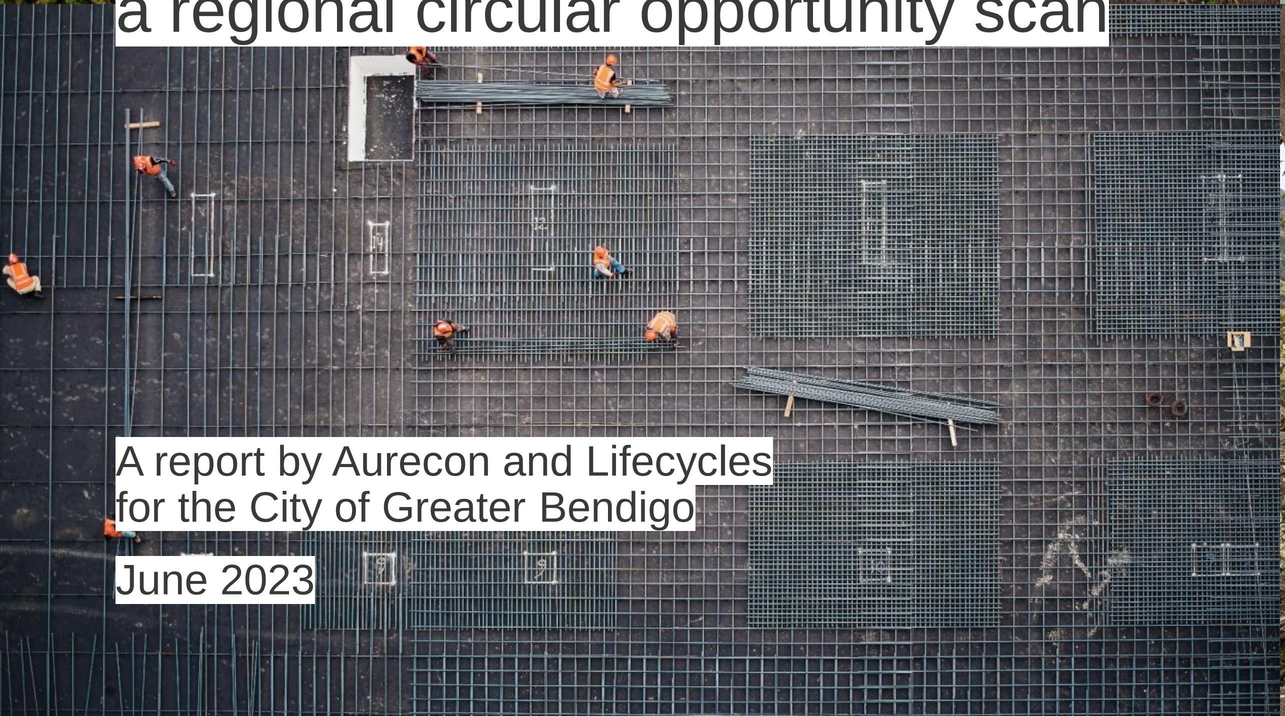
Circular Central Victoria

a regional circular opportunity scan



A report by Aurecon and Lifecycles
for the City of Greater Bendigo

June 2023

Thank you to the nine councils that contributed to this regional circular opportunity scan:

City of Greater Bendigo
Gannawarra Shire Council
Macedon Ranges Shire Council
Loddon Shire
Swan Hill Rural City Council
Mount Alexander Shire Council
Campaspe Shire Council
Mildura Rural City Council
Buloke Shire Council

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Sustainability Victoria

Project funding was also provided by the City of Greater Bendigo and former Loddon Mallee Waste & Resource Recovery Group.

Report prepared by Aurecon and Lifecycles

aurecon lifecycles.

Cover photos courtesy of [Invest London Mallee]

Aurecon and Lifecycles acknowledge and respect Victorian Traditional owners as the Traditional Custodians of Victoria's lands and waters. We celebrate the diversity of Aboriginal and Torres Strait Islander peoples and their ongoing cultures and connections to lands, water and skies across Australia. In particular, we acknowledge their ongoing connection to Country and continuing environmental stewardship.

We acknowledge and pay our respects to Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

Foreword

In a world of apparent decreasing circularity, down to 7.2% in 2023 from a paltry 9.1% in 2018 (CGRI, 2023) and in the face of increasing global consumption that has exceeded the Earth's ecological footprint every year since 1971, it is vital we adopt circular thinking to make better use of our wasted resources (Global Footprint Network, 2023). With Australia comfortably blowing through its fair share of global ecological and carbon budgets, by 4.8x and 11.9x respectively, it's vital that we move the circular economy (CE) discussion beyond recycling in Victoria (University of Leeds, 2018). That is, if we are to have even a remote chance of achieving the drastic reductions required for shifting Victoria's consumption to be back within the planet's sustainable physical limits. The following report represents a great example of local councils getting stuck into addressing the myriad of gaps we're seeing arise in ongoing attempts to take Circular Economy from a concept to a practical and positive application on-the-ground.

This report provides an exciting initial foray into quantifying the opportunity for circular economy interventions in (regional) Victoria, specifically, across the Loddon-Mallee and Loddon-Campaspe regions. Looking across the 9 participating local government areas, this report highlights the opportunities CE could play in further developing and invigorating regional areas. This includes tapping into the opportunity for decentralised circular industries to shift the dependency of Victorian (and Australian) regions away from metropolitan-focused infrastructure solutions and a fixation on market driven "scale". This decentralisation also represents an opportunity to address the tyranny of distance when it comes to viably recirculating waste(d) end-of-life materials.

Developed as a project by regional council officers due to a perceived lack of adequate action by other levels of government, the findings highlight the need for state- and federal-government to step-up and move the discussion beyond the 20th century topics of recycling, sorting infrastructure, and new kerbside bins. The circular economy is not a waste-issue, but an opportunity to future-proof regions, rebuild local industrial resilience and chip away at Australia's massive problem with overconsumption.

I hope you read this report both with hope and enthusiasm for the opportunities we could already be unlocking today through circular approaches, but also with the frank understanding that these opportunities will be a mere distraction if we don't deal with the underlying structural (un)sustainability issues Australia faces i.e. an economic and societal model predicated on continuing (un)economic growth and overconsumption beyond our planetary boundaries.

To end this foreword I'd like to thank the 9 participating local councils for their support and engagement in this project, the City of Greater Bendigo's Resource Recovery & Education team for its ongoing CE work, along with the Aurecon & Lifecycles project delivery team, and the Sustainability Victoria and the Loddon-Mallee Waste & Resource Recovery Group (now part of Recycling Victoria) for their part-funding support. Finally, I would like to leave you with this reflection as you read on:

We can't recycle our way out of this problem, and we can't circularise our way out of a system predicated on growing consumption, but with these report findings perhaps we can shift our focus in the right direction and snowball this into adequate local, state, federal and societal level activities. Let's hope we'll ultimately be quick enough to meet our climate targets, because trying to tweak the sustainability of our current linear society through CE initiatives driven at a local government level alone is like blowing into a (climate change intensified) storm.

Yours in circularity,

Dr. Scott T. Bryant

Circular Economy Coordinator @ the City of Greater Bendigo & Regional Circular Scan Project Lead

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Executive summary

The nine local governments in the Loddon-Mallee Region (the region) engaged Aurecon and Lifecycles to identify a set of circular economy opportunities for their region.

The project seeks to break the narrative around resource recovery in Victoria focused on waste and recycling efforts by council. And to identify and quantify new circular economy solutions where recovered materials and products are recirculated back into the local economy, ensuring environmental, social and economic benefits are realised for the region.

As momentum builds behind the circular economy, this is a timely and strategic piece of work. Moving to a circular economy opens exciting opportunities for the region to strengthen local economies, develop new markets, attract investment, and create jobs.

Ultimately the project identifies a pathway for the Loddon Mallee Region to realise the benefits of the circular economy. And to inspire action from other regions and jurisdictions and across industry, government and the community.

There are nine circular opportunities outlined in the report covering **organics, construction, consumer goods and manufacturing** sectors. They cover a range of circular interventions to move 'waste' up the hierarchy and keep resources circulating in the local economy for longer. The opportunities range from targeted supply chain interventions, transforming entire material value chains to create new value and products; as well as pursuing policy and system reforms to support circular outcomes.

The opportunities leverage insights and findings gathered from research, stakeholder engagement and targeted industry consultation conducted throughout the project, while addressing the key findings and recommendations from the upstream and downstream material flow analysis or 'Circular Scan'.

A Circular Scan was undertaken of available material flows from consumption and production data to identify potential material feedstocks (type, size and location) to target with circular interventions.

A key insight from the scan, was that recovery pathways for the large amount of agricultural waste produced in the region are limited. As such, the **organics** opportunities aim to create new value and products from available 'waste' streams through leveraging emerging technology and innovation.

The scan highlights that material recovery in the **construction** sector is relatively high and therefore targeting specific material flows will deliver limited impact. The construction opportunities instead focus on developing overarching strategies across the industry to encourage circularity from a wider perspective and implementing circular principles which retain maximum value of materials.

For **consumer goods and manufacturing**, the scan revealed that local recovery pathways for some waste flows were limited resulting in material being sent to Melbourne for processing. Local processing solutions were identified to enable recovery and reuse back into supply chains and end markets.

The total amount of material captured across all nine opportunities is **667,900t,** with feedstock inputs ranging from surplus fruit and vegetables, crop residues, animal manure, kerbside glass and plastics.

Each opportunity includes a framing of the problem to solve, details on how it would work including cost / investment and logistics, what it would look like at scale and next steps for local government, state government and industry.

A range of benefits have also been quantified for each opportunity to understand the economic and environmental potential and to support further business case development and implementation.

A snapshot of the nine opportunities and potential benefits is provided in Table 1.

The carbon modelling conducted for this study suggests that **418,000t** of greenhouse gas emissions would be avoided if seven of these circular opportunities were implemented at scale. Most of the estimated carbon benefits come from scaling production of sustainable building products made from wheat straw. This reflects the high amount of stubble available across the region for this particular opportunity, but also the difficulty in modelling diverse opportunities at an early stage.

While a conservative figure, the potential carbon benefits pursued through the circular opportunities represent an important step for the region in being able to take greater ownership over consumption emissions and embodied carbon across sectors.

In addition to the Circular Scan and circular opportunity development, several challenges and considerations for the region were identified through the research.

Recommendations on how the region can improve the collection, quality accuracy and granularity of data are provided in the Next Steps section of the report.

Executive summary

Another key insight gathered from the research was the significant regional challenges related to transport and access to infrastructure and markets. These challenges were not translated into specific opportunities as they require a larger infrastructure focused approach, potentially at the state / federal level.

Analysis is also provided around the nexus between circular economy and renewable energy in the region, and the opportunity to build upon their co-dependence as part of the sustainable transition and reduce the cost of the transition to a renewably powered circular economy.

Finally, the report concludes with a series of recommended next steps to support opportunity implementation.

As demonstrated through this project, local councils have a pivotal role to play in transitioning to a circular economy. To realise the circular vision for the Loddon Mallee Region, councils will have to significantly ramp up their efforts in this space. Key areas for action include;

- Mobilising networks and champions and build a coalition of brokers within the region to drive change across the three sectors.
- Building awareness of the benefits and required changes to industry to catalyse change and deliver education to the community to shift consumption patterns.
- Integrating circular procurement practices across councils and review asset management practices to extend the lifespan of council assets.
- Directing local council funding to support opportunity implementation and advocate for regulatory changes to state and federal governments to incentivise circular economy outcomes across industries and markets.

Table 1 is a snapshot summary of the nine circular opportunities including a description, type and volume of feedstock it targets, the circular intervention used, the estimated carbon emissions avoided and potential economic benefits.
For economic benefits, the number of dollar signs, signifies the scale of economic potential relating to regional investment, new job creation and new revenue streams.

Circular opportunity	Material input (p.a)	Circular economy intervention	Carbon benefit (p.a)	Potential economic benefit
1. Insect protein derived from food waste	70,000t of commercial + manufacturing food waste	Repurpose	**65,000t CO_2e avoided**	**$$**
2. Creating local food waste hubs to upcycle food waste	61,000t of fruit + vegetable produce waste	Repurpose Reuse	**9,700t CO_2e avoided**	**$$**
3. Anaerobic digestion for animal waste	20,000t of pig manure	Repurpose Regenerate	**650t CO_2e avoided**	**$**
4. Implement circular procurement across the councils	N/a	Reduce	**9,500t CO_2e avoided**	**$$**
5. Modular construction frames and fit out solutions	N/a	Reuse	**Not estimated**	**$**
6. Wheat straw in sustainable building materials	527,000t of wheat straw stubble	Repurpose	**330,000t CO_2e avoided**	**$$$**
7. Driving construction material reuse in the region	N/a	Reduce Reuse	**Not estimated**	**$**
8. Modular and transportable glass crushing infrastructure	9,900t of kerbside glass	Recycling	**245t CO_2e avoided**	**$**
9. Agricultural silage plastics recovery and recycling	1000t of silage plastic	Recycling	**2,800t CO_2e avoided**	**$**
All opportunities combined	**667,900t of material**		**418,000t CO_2e avoided**	

Table 1 – **Snapshot of circular economy opportunities and benefits**

2

Introduction and Approach

The nine local governments from the Loddon Mallee region engaged Aurecon and Lifecycles to identify a set of **circular economy priorities** for the area. The aim of this work is to quantify the scale of circular economy opportunities for the region and identify pathways to implementation.

The project involved investigating opportunities that extend the use and value of products and materials in the local economy and reduce dependence on virgin, non-renewable materials.

This was completed by analysing available material flows from consumption and production data, to identify a series of material and/or product circularity gaps and geographical intersections of 'waste' production and potential end users.

Desktop research and stakeholder consultation helped identify potential circular interventions that could be applied to narrow or close out material and production loops.

Once the circular opportunities were defined additional research and modelling was conducted to understand the potential benefits for each opportunity.

The project findings build on the regional priorities identified in the Regional Circular Economy Plans (RCEPs) developed by the Victorian Department of Environment, Land, Water & Planning (now known as DEECA).

Moving to a circular economy opens exciting opportunities for the region to strengthen local economies, develop new markets, attract investment, and create jobs. Accelerating this transition will involve private and public investment and coordination across industry, state and local governments. Ultimately this will reduce the region's dependence on Melbourne for technology and materials and enable greater ownership over consumption emissions and embodied carbon across sectors.

Overview of the Loddon Mallee Region

The Victorian State Government has five defined regions across the state, incorporating forty-eight regional and rural local government council areas.

The region in focus - **Loddon Mallee** occupies more than a quarter of Victoria and includes two sub-regions of Loddon Campaspe and Mallee. Covering 70,000 square kilometres, it is located along the Murray River which forms the border of Victoria and New South Wales.

The largest town in the region is Bendigo, located in the south-east, followed by Mildura in the north-west and Swan Hill in the central northern region.

One of the main economic drivers for the region is dry land farming and agriculture which is major employer. The region is also a significant consumer of energy particularly in the agriculture and manufacturing sectors.

The nine local councils in the Loddon Mallee region* that participated in this study are:

- City of Greater Bendigo
- Campaspe Shire Council
- Macedon Ranges Shire Council
- Mount Alexander Shire Council
- Buloke Shire Council
- Gannawarra Shire Council
- Swan Hill Rural City Council
- Mildura Rural City Council
- Loddon Shire Council.

*Central Goldfields Shire is also part of the Loddon Mallee region however did not participate in the study. This is because the project was partly funded by the Loddon Mallee Waste & Resource Recovery Group which Central Goldfields is not a participating council.

Figure 1 – **Map of Victoria by region**

Loddon Mallee Snapshot

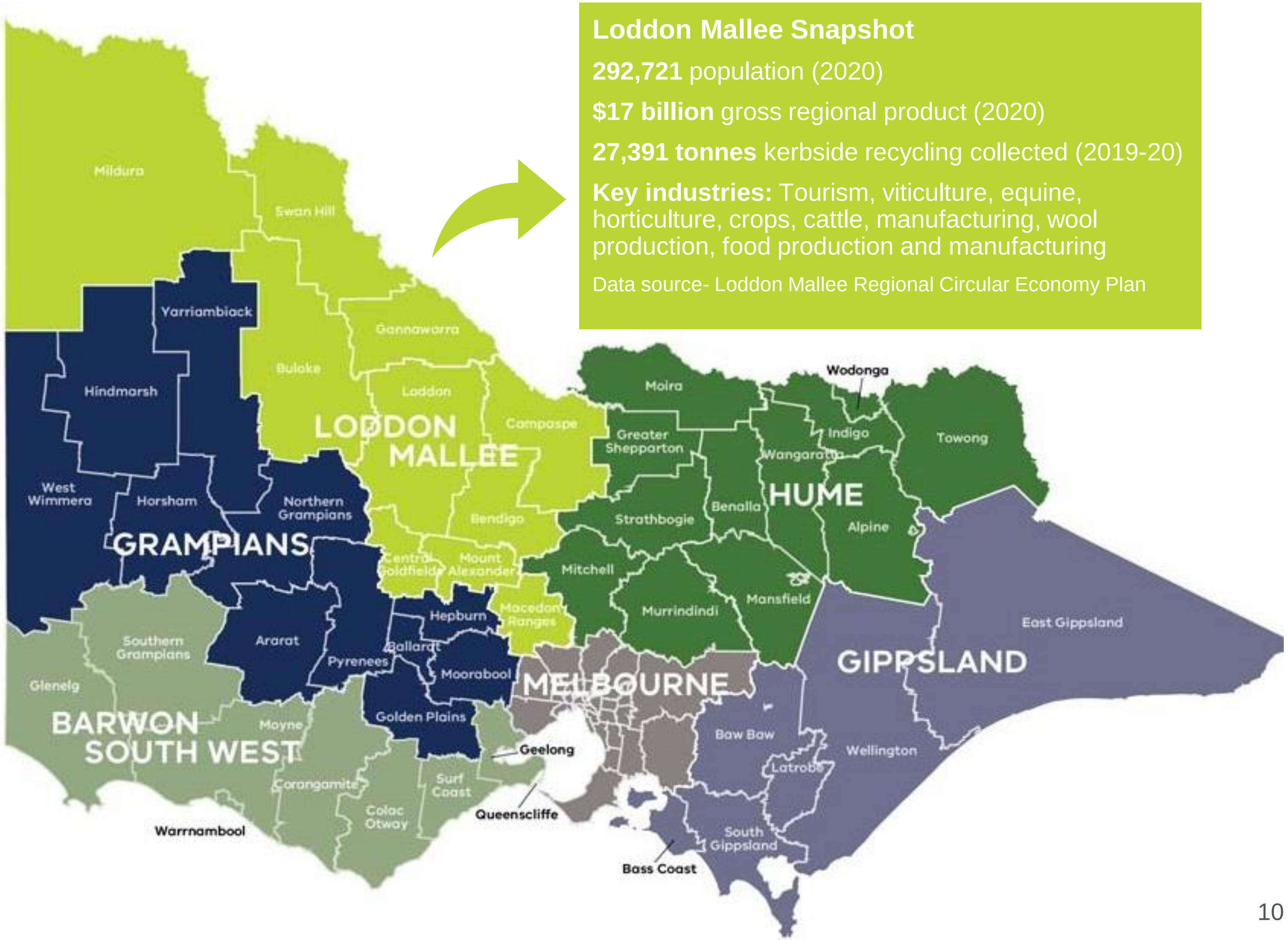
292,721 population (2020)

$17 billion gross regional product (2020)

27,391 tonnes kerbside recycling collected (2019-20)

Key industries: Tourism, viticulture, equine, horticulture, crops, cattle, manufacturing, wool production, food production and manufacturing

Data source- Loddon Mallee Regional Circular Economy Plan



Background
Loddon Mallee Regional circular economy plan

The circular opportunities and project findings build on and expand the identified regional circular economy priorities and actions.

In 2022, the Department of Environment, Land, Water and Planning (now DEECA) published a series of Regional Circular Economy Plans (RCEPS) for Victoria (State Government of Victoria, n.d.).

These plans set out the regions aspirations for 2030 for a sustainable and thriving circular economy.

They were developed through extensive regional stakeholder consultation across local and state government, businesses, manufacturers, social enterprise, the resource recovery sector and research and education institutions.

The RCEPs reflect local understanding of the regions strengths and challenges and identify a set of priorities and actions which can be used in the future development of a circular economy.

The areas covered by the nine local government councils involved in this report sit across two plans:

- The Loddon Mallee RCEP – capturing 8 of the 9 council areas (DELWP, 2022)
- The Hume RCEP – capturing Campaspe Shire (DELWP, 2022)

For the purpose of this report, we draw principally from the Loddon Mallee RCEP.

The Loddon Mallee RCEP identifies the following five circular economy aspirations to 2030:

1. Resource recovery is the primary focus, not waste
2. Product stewardship is paramount
3. Better use of plastic to support the circular economy
4. Consumers are supported to engage in the circular economy
5. Loddon Mallee is recognised a leader in the circular economy in Victoria

Thirty one priorities or actions are organised under six themes or 'key enablers' shown in Figure 1.

Aligning the regional aspirations and priorities with on the ground circular opportunities.

The RCEP's provide the strategic context and direction for Loddon Mallee's circular transition. The next important step in this journey and a key objective of this study has been to translate the RCEP aspirations into on the ground actions. And in doing so, articulate the scope, scale and impact of material, product or industry specific circular economy interventions for the region.

Both bodies of work are aimed at positioning and recognising Loddon Mallee and Campaspe as a leader in the circular economy in Victoria.

Figure 2 – **Key enablers in Loddon Mallee's RCEP**

Background
The circular economy is a systems approach

The circular economy is an exciting opportunity to create sustainable jobs in our communities that make best use of resources.

In today's linear economic model, virgin materials are extracted, manufactured into products, used, and then discarded as waste. This linear approach is inefficient, depleting natural resources, generating greenhouse gas emissions and creating waste.

Circular economy frameworks use **systems thinking** to shift the way assets and products are designed, manufactured, consumed, and discarded by:

1. **Designing-out waste:** use resources efficiently to prevent waste from being generated throughout the life cycle, avoid using chemicals or materials that may render reuse and recycling impossible.
2. **Keeping assets at their highest value:** retain materials in circulation - as products, components, or raw materials - for as long as possible. To achieve this, assets should be designed for recovery and return to the system, whether by reuse and recycling or through processes such as composting and anaerobic digestion.
3. **Regenerating natural systems:** rebuild soils, increase biodiversity, clean pollution in a shift from "less harm" to actively doing good and helping replenish ecosystem services.

Thinking and working in systems is required to reach the true potential of the circular economy. This means mapping complex problems and identifying interdependencies across supply chains to develop of solutions rather than working on many parts in isolation.

It also means collaborating across stakeholders including businesses, governments, research and civil society; and committing to work together to create a more sustainable, resilient and equitable future.

According to Victoria's Circular Economy Business Innovation Centre – CEBIC

Our vision is for a circular economy that continually seeks to reduce the environmental impacts of production and consumption, while enabling economic efficiency through productive use of natural resources.

It allows us to avoid waste with good design and effective recovery of materials that can be reused. It promotes more efficient business models that encourage intense and efficient product use, such as sharing products between multiple users, or supplying a product as a service that includes maintenance, repair and disposal. The value we obtain from the resources used to create goods and services increases.

It transforms our linear economy mindset – take, use and throw away – and fosters innovation and productivity that invigorates existing businesses and creates new ones, delivering more jobs, more growth and more social inclusion to the local, regional, state and global economies.

(CEBIC, 2021)

The circular economy is a systems approach to:

DESIGN OUT
waste and pollution

RETAIN
value in assets and materials

REGENERATE
natural systems

A three-phase delivery

The project findings draw together quantitative modelling, desktop research, local data and stakeholder insights to identify the set of circular opportunities for the region.

Stakeholder reference group

A key objective of this project was to build a shared understanding among stakeholders on the circular opportunities for the region. A stakeholder reference group was established early in the project and regularly engaged via online workshops and targeted 1-1 interviews to inform, test and validate the findings.

Testing the analysis and opportunities with the stakeholders who had on-the- ground regional experience with challenges and success in this space to date, was a critical part of the project. The contributions and insights shared by stakeholders actively shaped the circular opportunities explored. Data gathered on barriers and implementation pathways is reflected in the final set of nine circular opportunities.

The stakeholder reference group consisted of representatives from the following government and industry organisations:

- Loddon Mallee councils: City of Greater Bendigo, Campaspe Shire Council, Macedon Ranges Shire Council, Mount Alexander Shire Council, Buloke Shire Council, Gannawarra Shire Council, Swan Hill Rural City Council, Mildura Rural City Council, Loddon Shire Council.
- State government agencies – Recycling Victoria, Agriculture Victoria, Regional Development Victoria, DEECA.
- Business and industry – Dairy Australia, Pork Australia, Mildura Regional Development, Kyneton Ridge (wine industry).

Figure 3 **– Overview of project methodology**

Circular scan and sector analysis
Oct-Dec 2022

Opportunity identification and investigation
Dec-Jan 2022

Opportunity prioritisation and development
Feb-April 2022

Stress testing with stakeholders

Data was collected from a range of inputs to provide a baseline and resource flows mapped across organics, construction and consumer goods and manufacturing.

The data analysis was used to develop sector profiles and circularity gap insights, including the types, volumes and locations of materials that could be targeted for circular interventions. The circular scan was developed iteratively, with the opportunity identification affecting the scope of the scan and vice versa – focusing research on flows around likely opportunities. The results of the scan do not provide a complete picture of all material flows in the region.

The sector profile insights were shared and tested with the stakeholder reference group in December 2022.

The circular scan is detailed in Section 3 of this report and supporting datasets are provided in Appendix A.

Based on the insights from the circularity scan, the stakeholder reference group brainstormed an initial list of circular economy opportunities for investigation. This was facilitated at an online workshop in December 2022.

Local and internal case studies were also presented to workshop participates as inspiration of what could be possible.

Fifteen opportunities were shortlisted for further investigation.

Targeted research and investigation was conducted to gather information on the potential scope, location and impact for each circular economy opportunity.

The full list of circular economy opportunities explored is detailed in Section 4 of this report.

The opportunity investigations were brought back to the stakeholder reference group at another online workshop in February 2023.

The opportunity investigation results were tested with stakeholders to identify

- further insights on potential implementation pathways
- data for input to a multi-criteria assessment to evaluate the potential impacts and ease of implementation.

The workshop outcomes were used to prioritise the final set of nine opportunities for further development.

Additional research and modelling was conducted to understand the potential economic, circular economy and carbon emission impacts of each opportunity.

The findings are detailed in Section 4 of this report.

3

Circular scan

To transform the linear economy into a circular economy it is necessary to focus on both supply and demand.

Circular Supply processes are those which have material currently wasted or underutilised which can be sourced as inputs to circular flows.

Circular Demand processes are those which currently have potential to utilise secondary or lower impact inputs. These processes are currently using virgin materials and supplying valuable goods and services to the economy.

The circular scan stage of this study looks to identify major material flows coming into (circular demand) and leaving (circular supply) the most prominent sectors within the Loddon-Mallee and Loddon-Campaspe regions. This is done with the aim of identifying where circular economy interventions should focus in order to reap the greatest benefits in terms of material circularity. The results of the circular scan are used to develop a set of circular opportunities taking into account the specific context of the region.

Circular scan methodology overview

Identifying material flows that are relevant to the region and have the most potential to be cycled locally helps focus on local circular opportunities.

Factors including economic output, regional relevance and expected potential for circular opportunities specific to Loddon-Mallee and Loddon-Campaspe were considered in selecting the following key sectors to explore:

Organics

Flows of organic material are most strongly related to the agricultural sector, though occur also in food manufacturing, households and hospitality. Agriculture accounts for approximately 10% of total economic output in the region (REMPLAN, 2023). This is higher than the national average (3%), indicating that agriculture is particularly relevant to the Loddon-Mallee region. Agriculture produces diverse forms of organic waste that could possess unexplored pathways for recovery. It is also expected that technology for potential solutions already exists.

Construction

The construction sector accounts for 12% of total economic output in the region (REMPLAN, 2023), in line with the national average (13%), indicating that construction is strongly correlated to population. In general, recovery of materials from demolition tends to be quite high, though materials are often bulky and low value, presenting logistics challenges. Circular opportunities in construction may provide the greatest benefits when taking a systemic approach, as opposed to focusing on recovery of wastes.

Consumer goods and manufacturing

In the region, manufacturing accounts for 21% of total economic output (REMPLAN, 2023). This is significantly higher than the national average (10%), indicating that manufacturing is particularly relevant to the region. These types of products tend to have relatively high value and therefore have also been the focus for improving circularity generally. Consumer goods and manufactured products lend themselves well to circular opportunities which aim at maintaining value through lifetime extension and ensuring end-of-life recovery.

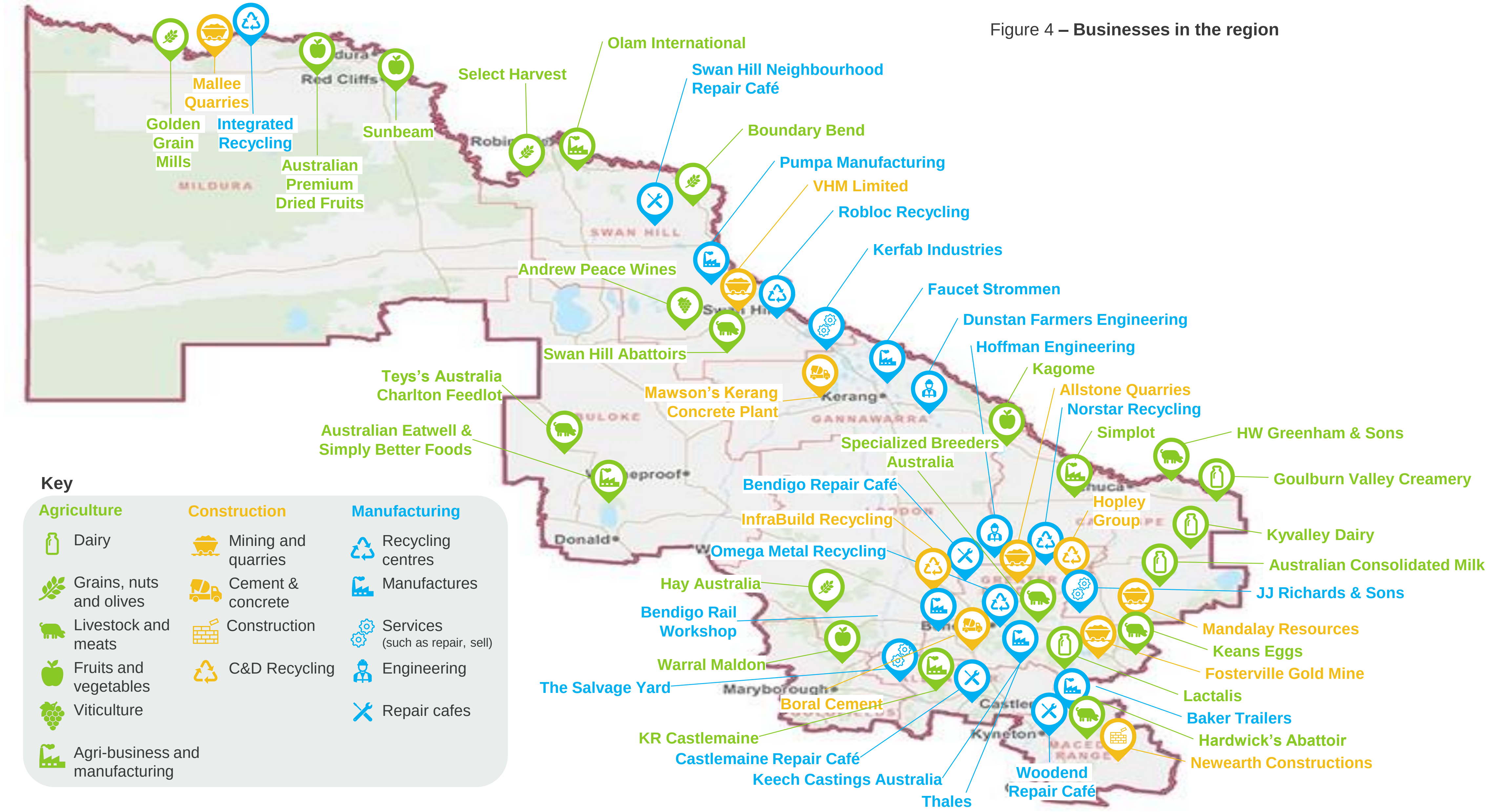
The distribution of businesses and activities in each of the key sectors areas are mapped on the following page.

While trade and services account for the largest portion of economic output in the region (52%), these sectors are known to have low materiality and are hence not targets for circular opportunities. The three sectors chosen for this analysis make up the next largest in terms of outputs. Mining and utilities make up the last 6% of total output and have not explicitly been included in the circular scan.

Within the three sectors selected, the aim is to identify the volumes and where possible, the locations of major material flows. This is a complex exercise, involving piecing together data from multiple sources of varying quality and uncertainty. For this reason, the collection of material flow data has been focused on where opportunities are likely to be applied. The process has been iterative, with the opportunities development influencing the circular scan and vice versa. The results of the circular scan do not represent a complete picture of all material flows within the region.

Loddon-Mallee Region business ecosystem

Figure 4 – **Businesses in the region**



Circular scan methodology overview

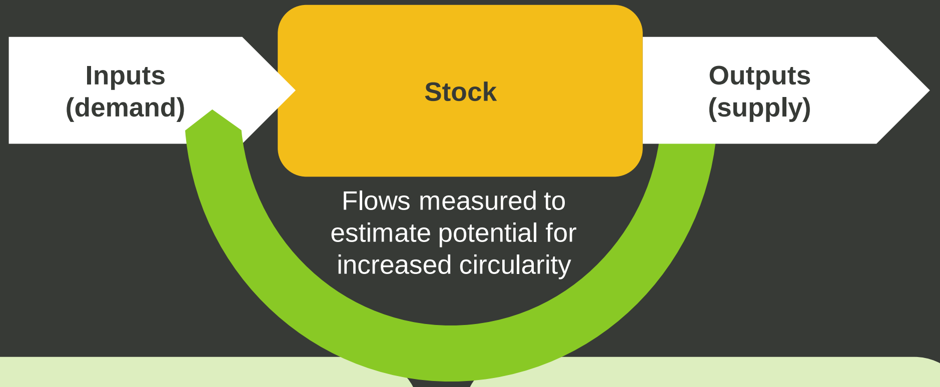
The key data sources for the study are shown to the right.

Whenever possible, data sources were chosen which were represented in physical flows. When this data was not available, the estimation of flows utilised economic data from the region in the form of input-output tables. This methodology is highly effective at identifying the interactions between sectors, but comes with limitations.

Due to the categorisation of the economy into 114 sectors, many processes are aggregated and hence the data represents an average of all the subsectors within it. Furthermore, since the data is in monetary form, it is converted into physical mass values using price data which is highly variable. Hence a change in commodity prices can have a significant effect on the final result. Input-output analysis was only applied to generalised areas, i.e. it was not used to estimate flows for specific materials or producers.

Specific methodologies for each of the three focus sectors can be found in their respective sections of this report. Since multiple data sources have been used, the flow diagrams do not represent one specific year of data.

Figure 5 – **Circularity potential from inputs and outputs, including key data sources**



Circular demand data sources

RMIT building materials study (RMIT Centre for design, 2006)

Existing internal models by Lifecycles

Loddon Mallee Economy summary tables 2022 (REMPLAN, 2023)

Circular supply data sources

2020 National waste database (DCCEEW, 2020)

Bin audit data from the region

Agricultural Commodities, Australia 2020-21 (ABS, 2021)

National Food Waste Baseline (ARCADIS, 2019)

Organics material flows

Sector description

Regional organic waste streams with recovery potential can be broken down into the following four areas:

1. Agricultural residues

The region is a major food production region with a large economy in the farming sector, including viticulture, horticulture, broadacre crops, and livestock.

Cereal crops, especially wheat and barley, are the largest agricultural product of the region by mass. Other major agricultural products include canola, pulses such as lentils, grapes, sugar cane, tomatoes, olives, almonds and sheep.

Around 70% of the region's cereal production originates in the Mallee, with Buloke producing approximately half of all the Mallee's cereal crops. Fruit, vegetable, and cattle production occurs primarily in the regions close to the Murray river. Campaspe, Swan Hill, and Mildura lead the region for fruit and vegetable crops. Cattle are more congregated in the Loddon-Campaspe, with Campaspe, Gannawarra, and Loddon being key suppliers.

The significant production of agricultural goods in the region leads to agricultural waste:

- **crop residues** include the parts of the plant not kept for sale (such as straw, husks, hulls, shells, stalks, leaves and seed pods...)
- **produce waste** include waste of the actual products (such as tomatoes, olives, lentils and wheat...) and may arise when fruit and vegetables don't meet retail standards, excess fruit and vegetables are produced, or from waste occurring during picking.

There are already some recovery pathways for agricultural waste in the region that could be scaled up, for example:

- biomass power plants, such as almond hulls for electricity and potash generation (Select Harvest, n.d.)
- manufacture of wall and ceiling panels from wheat stubble residues (Ortech Industries, 2022)
- generation of gas and electricity from piggery effluent (Inoplex, 2022).

2. Industrial organic waste

Organic waste occurring in industry include food manufacturing waste such as packhouse waste, blemished fruit and vegetables, peels from canning, pulp from juicing, and whey from dairy product manufacturing.

3. Commercial food waste

Commercial organic waste includes leftover food from hospitality as well as institutions such as schools and hospitals. These flows are typically not well understood but are highly correlated to population.

4. Domestic food and organic waste FOGO

Households also generate a green waste stream consisting of food waste, garden waste, and other organic materials. This waste stream is already used for various applications. Garden organics processed at transfer stations and landfills are currently chipped and spread, turned into mulch, or sold to the public. Food and garden organics (FOGO) are also composted at in-vessel facilities outside the region.

The circular scan for organics seeks to identify volumes of wastes that can be used to improve circularity of the region. This is done by first creating an overview flow diagram to get an idea of the relative sizes of different flows.

A more detailed analysis is then performed to quantify flows that tie-in to known circular opportunities that were identified through the stakeholder engagement process. These are:

- wheat straw
- on-farm produce waste
- commercial food waste
- food manufacturing waste
- piggery effluent

Methodology and data sources

Data on agricultural commodities in the region were obtained from the 'Agricultural Commodities, Australia, 2020-21' release (ABS, 2022). The regional production data was extracted from the Loddon Mallee Region. Agricultural waste factors for specific agricultural products (such as ratio of sheep mortalities to sheep produced, ratio of almond hulls and shells to almond production...) were procured using data from sources, including the National Food Waste Baseline (ARCADIS, 2019) the Australian National Life Cycle Inventory v1.38 database (ALCAS, 2022), and scientific journal articles on agricultural production.

For mapping and visual inspections of the data, SA2 region shapefiles (ABS, 2022) were parsed in QGIS with the extracted agricultural commodity and waste data.

The Sankey diagram for organics in the region was created using eSankey software. Flow data was sourced from the analysed ABS agricultural commodity data, the National Food Waste Baseline, local council bin audit data, the Loddon Mallee Region Renewable Energy Roadmap, and the Loddon Mallee Waste and Resource Recovery Implementation Plan 2016–26.

Organics material flows

Discussion of results

Organic material flows in the region are dominated by agriculture – indicating that the most significant benefits can be made by focusing on utilising the organic wastes associated with agricultural production.

As cereal crops are the largest agricultural product, cereal stubble waste dominates the agricultural residues flow from the region, presenting an exciting circular supply opportunity. If wheat stubble is left on farm for yields below 1.33 tonnes/ha for soil carbon purposes, more than 500,000t of stubble remains for use.

Around 61,000t of on-farm produce waste is generated, primarily tomatoes. This excludes sugar cane waste as markets for bagasse are already well-established. Although this flow is smaller than broadacre crop residues, it is a high value stream, with potential for upcycling.

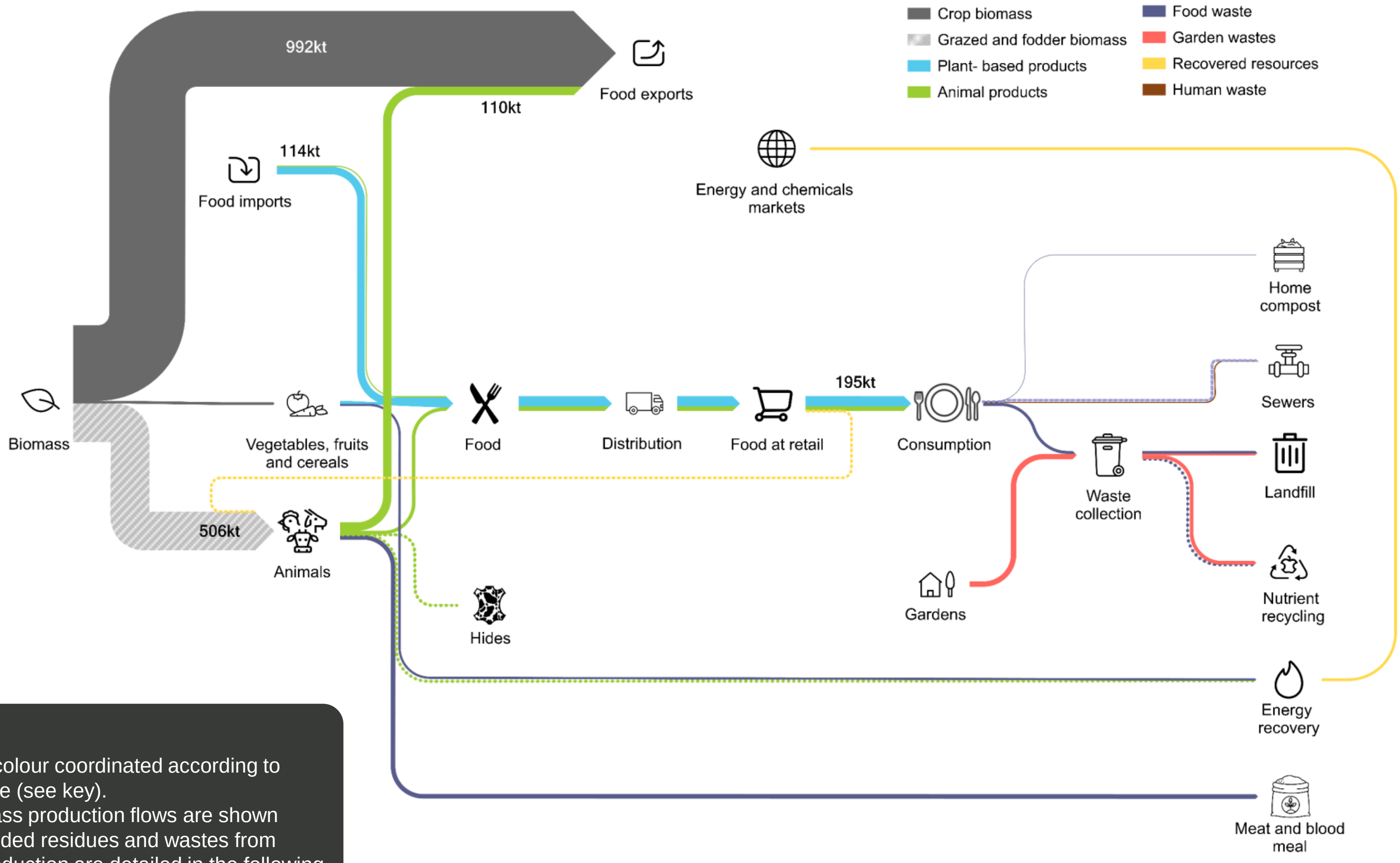
In terms of livestock, Campaspe leads the region in cattle and pig production, while Loddon is a major supplier of poultry and sheep. Around 600,000t of pig effluent is generated annually.

Around 16,000t of commercial food waste is generated annually. While post-industrial organic waste from food manufacturers is difficult to quantify as it requires producer-specific data, we estimate it to be around 54,000t, based on scaling national data to relative food manufacturing industry size of the region.

Reading this Sankey diagram

- Wider arrows represent larger flows.
- Flows smaller than 10kT were too small to see, and have been artificially widened and dotted.
- Over 6 million tonnes of crop biomass are going into animal feed and exports. These flows were scaled to a quarter in this diagram to improve legibility.
- Flows are colour coordinated according to product type (see key).
- Only biomass production flows are shown here. Excluded residues and wastes from primary production are detailed in the following diagrams.

Figure 6 – **Organic material flows in the region**



Organics material flows

Around 16,000t of commercial food waste is generated annually. While post-industrial organic waste from food manufacturers is difficult to quantify as it requires producer-specific data, we estimate it to be around 54,000t, based on scaling national data to relative food manufacturing industry size of the region.

Recommendations

1. Target uses for cereal stubble flows
The large quantity of cereal stubbles produced in the region creates an opportunity to put these waste products to use in high value products.

2. Target uses for on-farm fruit and vegetable waste
There is a significant amount of agricultural on-farm waste of fruit and vegetables (such as unharvested crop, rejected product...). An opportunity exists to use these as circular supply products, for example, upcycling into food products.

3. Further investigate uses for livestock effluent such as pig manure
There is potential to utilise wastes such as pig manure, cow manure, and dairy effluent for energy recovery, for example through anaerobic digestion.

4. Investigate options to use commercial and food manufacturing waste
Food waste from commercial sources such as hospitality, schools and hospitals, as well as food manufacturing waste could also be recovered. One example would be for use as an input to insect protein for animal feed

Table 2 – **Organics sector material outflows**
(see Appendix A for calculation assumptions)

Material type	Tonnes available per year
Wheat straw	527,000
On farm produce waste	61,000
Pig effluent	600,000
Commercial food waste	16,000
Food manufacturing waste	54,000

Figure 7 – **Commercial and manufacturing food waste in the region**

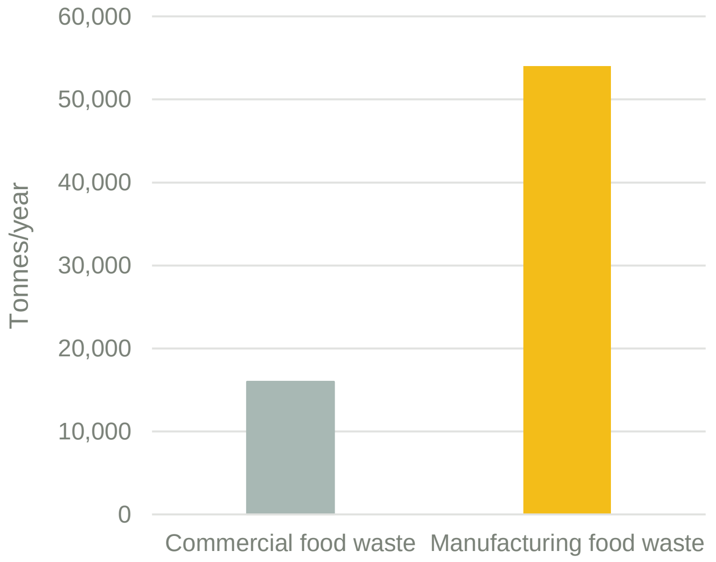
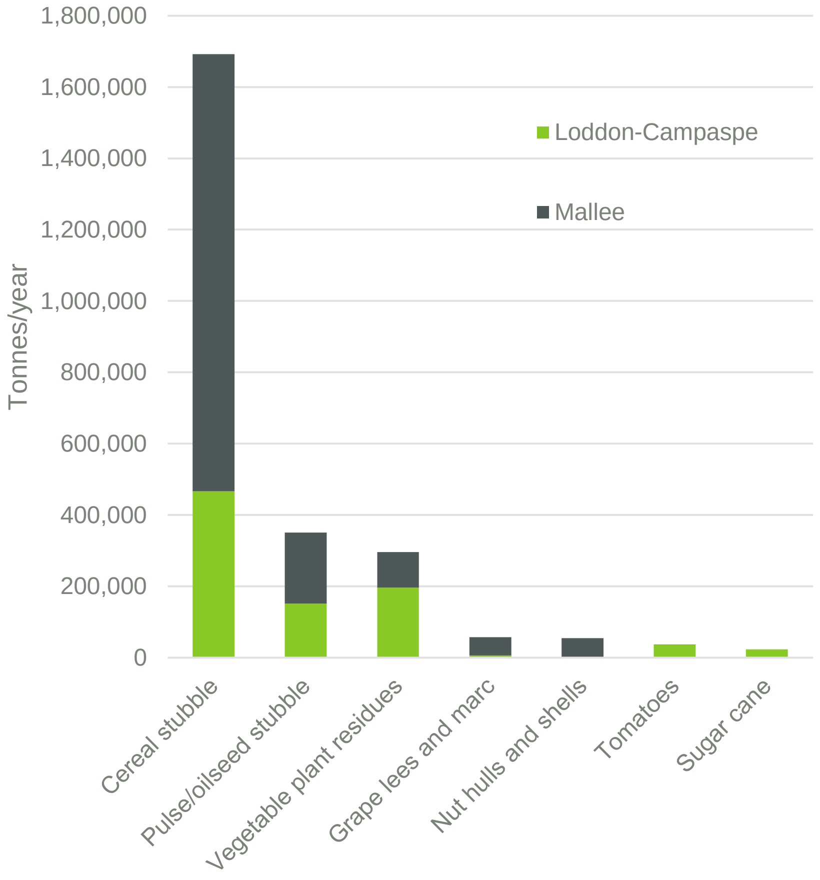


Figure 8 – **Top 7 agricultural wastes produced on farms in the region**

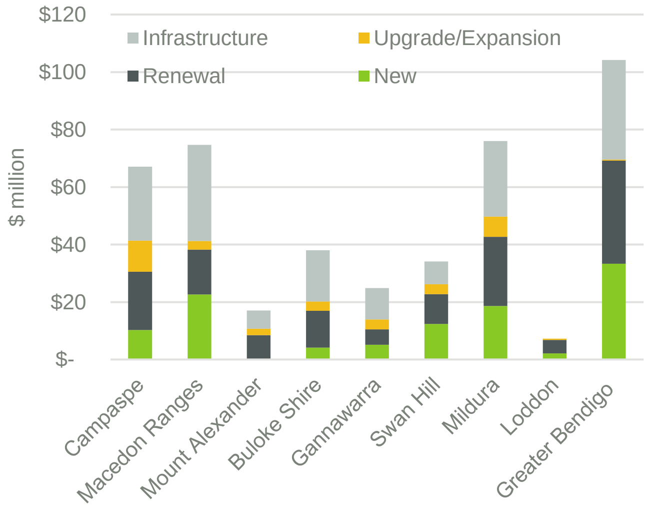


Construction material flows

Sector description

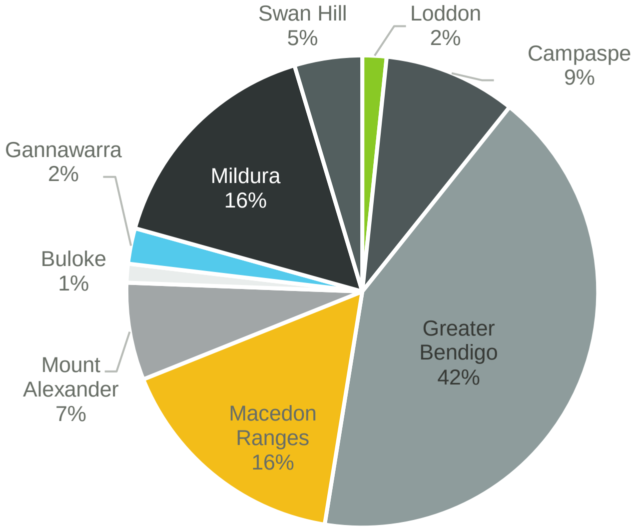
Local governments operate significant capital works programs to build and maintain new and existing infrastructure and assets. Across the nine councils, 2022-23 budget expenditure on capital works projects was over $280 million, with $170 million allocated towards infrastructure projects. The breakdown of this spending is shown below, including spending on infrastructure and spending on property and plant & equipment (by new, renewal and upgrade/expansion). The capital works budgets indicate that most council-funded construction is happening in Bendigo, Mildura, Macedon Ranges and Campaspe.

Figure 9 – **Council capital budgets, 2022-23**



New residential construction is estimated at 4,500 new dwellings annually, driven by both population increase and the replacement of old houses (ABS, 2023). Shown above is the distribution of new residential construction across local government areas. Similar to the capital works construction, the largest amounts are in Greater Bendigo, Mildura and Macedon ranges. Along with privately funded non-residential construction, these subsectors form the construction sector of the Loddon-Mallee Region.

Figure 10 – **New residential construction, 2022**



Methodology and data sources

Annual new residential construction was derived from ABS statistics, considering population growth and replacement of dwellings after 50 years. This was used to scale the material flows into residential construction drawing on a model developed by the Centre for Design at RMIT (2006) that estimated the types and amounts of materials flows into different types of construction.

For non-residential construction (including infrastructure, commercial properties and other non-residential buildings), the analysis used economic data in the form of 114-sector input-output tables (REMPLAN, 2023) and shows the spending between sectors and final demand from different consumers. Data analysis performed on these input-output tables determined the amount spent by different consumers (government final consumption expenditure, private investment, and public investment) on different construction types (non-residential, civil engineering, and construction services). Spending was then narrowed down to sectors relating to construction materials, such as steel and wood product manufacturing. The data was then converted from financial units to mass units using price data.

The above findings were then aggregated to form the total inputs into the region's construction sector.

On the output side, the 'circular supply' materials were estimated by scaling data from the 2020 National Waste Database by population (DCCEEW, 2020).

Finally, both the inputs (circular demand) and outputs (circular supply) flows were combined to form a Sankey diagram, created using eSankey software.

Construction material flows

Figure 11 – **Construction material flows in the region**

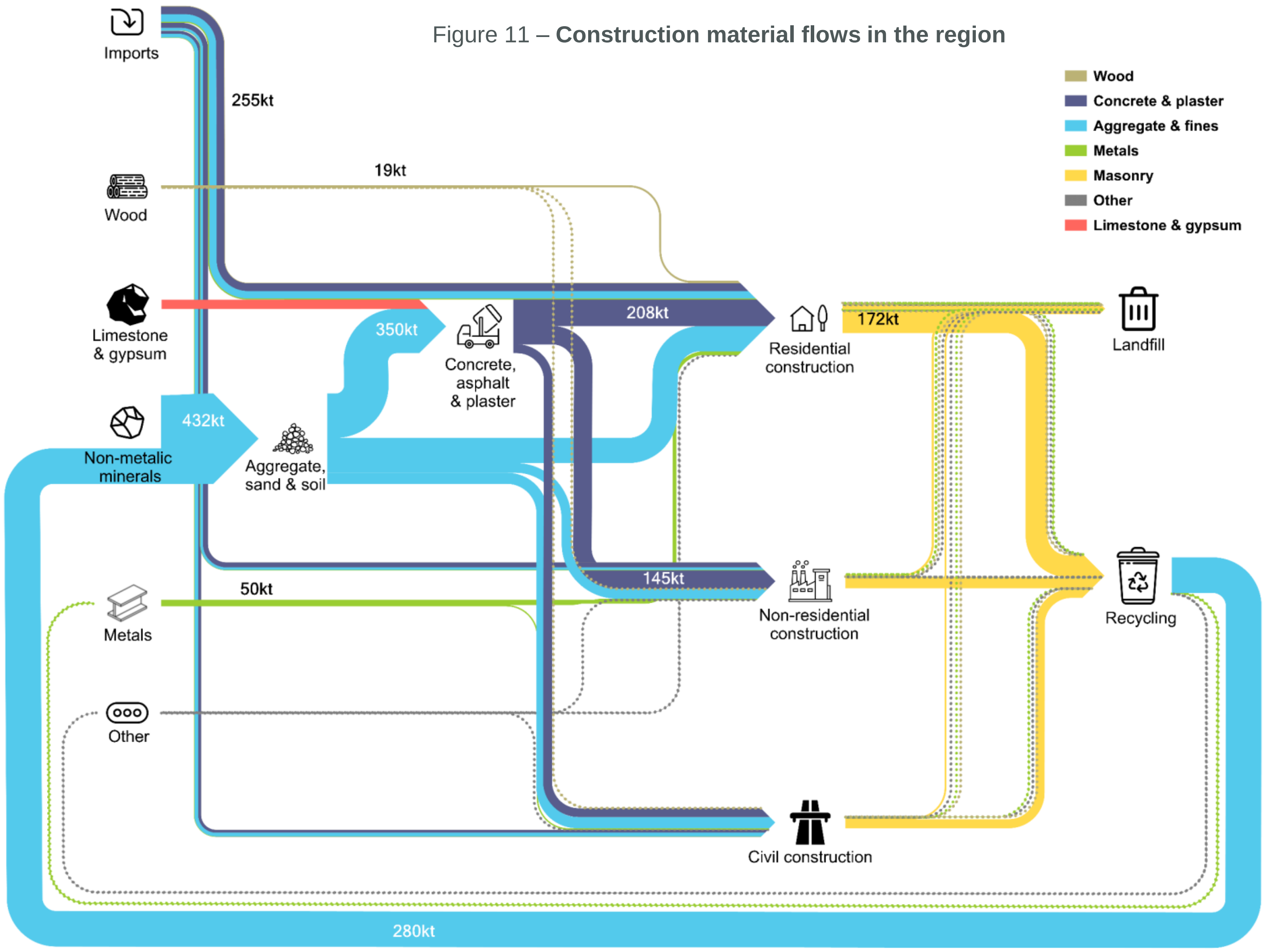


Table 3 – **Construction sector inflows and outflows**

Construction sector	Total inflows (demand) tonnes	Total outflows (supply) tonnes
Residential	588,000	229,000
Non-residential	299,000	109,000
Civil	228,000	90,000

Reading this Sankey diagram

- Material flows are broken down into two construction types: residential construction and non-residential construction. Residential construction includes all residential dwellings, while non-residential construction includes infrastructure, commercial buildings, and other non-residential buildings.
- Flows smaller than 10kT were too small to see, and have been artificially widened and dotted.
- Different data sources have been used on the input and output sides, and hence the categorisation of materials varies as well. This is why the flows coming in and going out of the two construction types are not the same colours.
- Flows going into the two construction types are larger than the flows coming out. This difference can be explained by the increase in building stocks as more construction is needed to service an increasing population.

Construction material flows

Discussion of results

The circular scan results give insights into the types and volumes of materials entering and leaving the construction sector in the Loddon-Mallee region. On the input side, the largest flows into residential and non-residential construction are concrete/plaster, 208kt and 145kt respectively. the second-largest flows in these sectors are of aggregate and fines. The largest flow into civil construction is aggregates, with 88kt.

On the output side, these largest flows also have high rates of recovery, with almost 90% of materials recovered for both metals and masonry materials. However, it should be noted that these figures are based on data from Victoria as a whole and therefore do not consider logistical challenges in recovering materials from rural areas which may affect regional recovery rates. Recovery of metals is particularly important for reducing impacts as they are easily recycled into new materials which directly offset the need for virgin metals. While recovery of metals is generally high, the circular scan results show that the recycled content of metals entering the sector is relatively low. This indicates a significant potential to utilise more recycled metals in construction of new buildings and infrastructure if supply is available.

While masonry recovery is also important, this is considered a low-value recycling. Typically, masonry materials recovered, such as concrete, bricks, asphalt and rubble are crushed and used as aggregate in new concrete. While this is technically recovery, it only avoids the need for new aggregate – a low impact material – and hence the benefits of recycling are limited. Further analysis could be done to investigate recycling rates of the region specifically, to gauge whether improvements could be made in recovery of metals and masonry.

For masonry materials, more value can be obtained from the materials by intervening with circular economy strategies at an earlier point and enabling recovery of *components* rather than recovery of *materials*. For example, if bricks are recovered, cleaned and reused rather than crushed, the need for new bricks is avoided, rather than the need for new aggregate, creating larger climate change and circular economy benefits. This value-focused approach applies to all materials at end-of-life.

For the construction sector in general, focusing on specific flows can only provide limited circularity benefits. The construction sector can see more significant circularity improvements by assessing the systems within the industry and developing overarching strategies which are implemented to encourage circularity from a wider perspective. This may come in the form of minimising material flows through lifetime extension, enabling circular interventions that keep components at highest value, or maximising utility of existing assets.

It should be noted that material streams coming out of the construction sector will not necessarily equate to potential streams for recovery. Depending on disassembly practices, some streams may be mixed together or unable to be separated – for example glued or welded. Because this analysis is primarily based on regional spending, locations of flows are not analysed. However, since closely linked to population, larger flows will occur in higher population areas.

Recommendations

1. Develop a system which supports reuse over recycling

Reuse of components and materials retains more value and has larger environmental benefits than recycling. Reuse in construction will not happen without the right conditions. To increase use of reused components, a system is needed to intentionally provide incentives to:

- Separate and collect materials at the demolition stage,
- Store and resell these components, and
- Source reused components in the construction stage.

2. Focus on material sourcing

Recovery rates at end-of-life appear to be high, but there is less visibility on recycled content feeding into the sector. Using recovered materials in construction presents an opportunity to increase the circularity of the sector.

This could be achieved through increasing recycled content in metals and plastics, selecting low-impact materials made from waste, and replacing non-recoverable materials with recoverable ones

3. Implement circularity principles which retain maximum value of materials

Maximum value is retained by following the circular economy hierarchy and prioritising lifetime increase and reuse over recycling.

The construction sector also presents opportunities for other circular economy interventions such as increased utilisation through sharing, adaptable interiors or multi-use facilities.

Consumer goods and manufacturing material flows

Sector description

Manufacturing is the second largest industry in the region after services. Manufacturing businesses within the region include industrial parts such as steel castings (Keech), material handling equipment (Kerfab), military vehicles (Thales), tapware and fittings (Faucet Strommen), and recycled plastic products (Integrated Recycling).

In addition to equipment and parts production, there are several agricultural product and food production businesses in the region, including but not limited to dairy products (Goulburn Valley Creamery, Lactalis), poultry products (Hazeldene's Chicken Farm), smallgoods (KR Castlemaine), tomato paste (Simplot), grain products (Golden Grain Mills), and dried fruit (Sunbeam). These businesses are evenly spread out through Loddon-Mallee, with the majority located closer to the Murray River border of the region.

Some wastes generated by these industries can be recovered using existing local systems but other material types can be a challenge. For example, the dairy industry is a big part of the Loddon-Mallee economy (as evidenced by the congregation of dairy manufacturing businesses in Bendigo-Campaspe shown in Figure 4). Wastes such as silage wrap are hence produced in significant volumes. However, at the end of life a lot of this plastic is burned instead of recycled. There is also an opportunity for more circular supply using the wastes produced by the dairy cattle industry (centred around the Campaspe region, where dairy cattle is most dense).

On the consumer goods side, consumption is expected to closely follow national averages, without any patterns specific to the region.

Methodology and data sources

Estimating manufacturing material flows presents a challenge for data collection, as mass balances are often considered proprietary information and not made publicly available.

For this reason, the approach to the circular scan for this sector is highly influenced by discussion which occurred during the exploratory workshops with key stakeholders. Participants in these workshops provided first-hand accounts of material flows which are currently presenting challenges with respect to circular economy solutions.

This discussion mostly highlighted waste streams which are difficult to recover or difficult to find end markets for, such as mattresses, e-waste, glass bottles and silage wrap. Based on data available, the following two flows were quantified:

- silage plastics
- household glass.

In order to present a balanced approach, the demand side was also investigated, by mapping the industry sectors which consume the most metals and plastics using REMPLAN input-output data for the region. The purpose of this exercise was to identify potential users of circular materials. This is supplemented with additional research into significant consumer goods and manufacturing industries within the region.

Consumer goods and manufacturing material flows

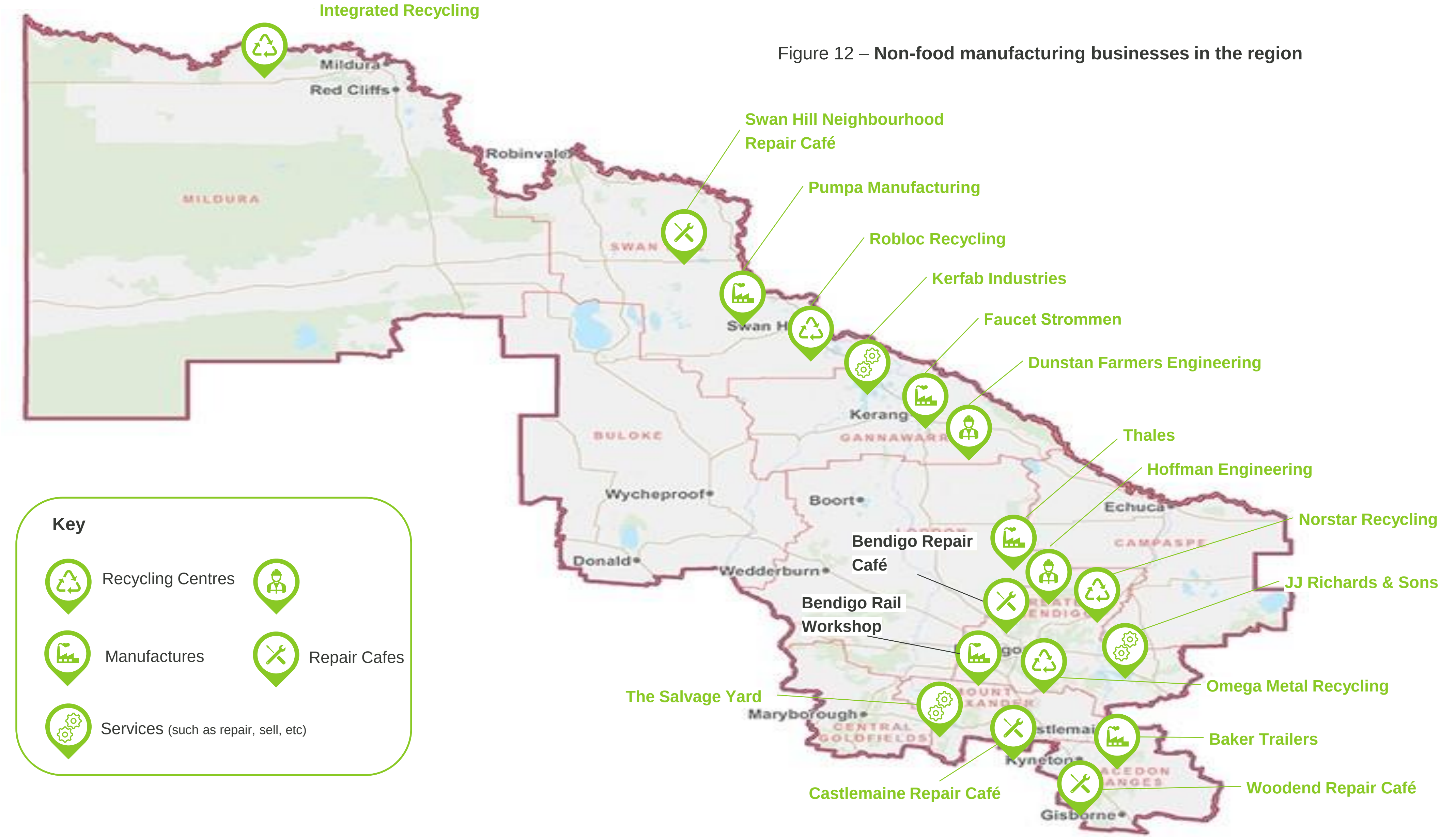


Figure 12 – **Non-food manufacturing businesses in the region**

Consumer goods and manufacturing material flows

Discussion of results

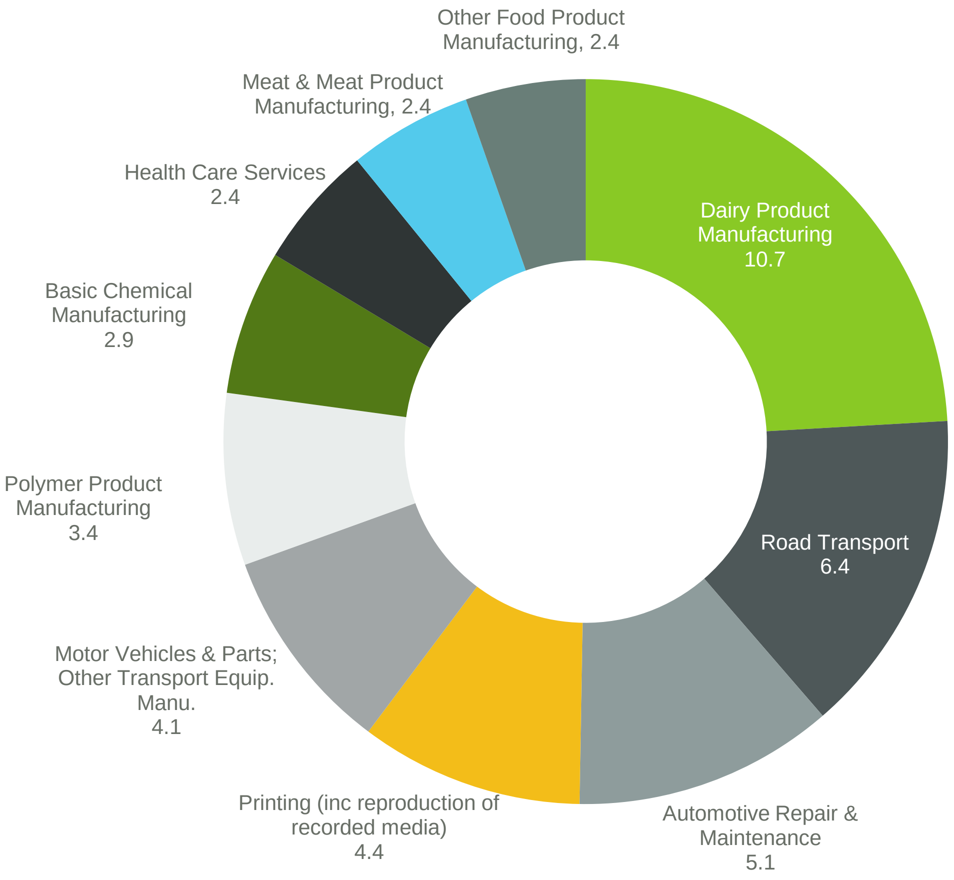
The circular scan for consumer goods and manufacturing focused on identifying top industry users of plastics and metals. Stakeholders were also consulted to gain a wider picture of materials flows with potential circular economy opportunities.

The biggest industry consumer of plastic is in dairy product manufacturing, with approximately 10.7 kt plastic consumed annually. Since this analysis was performed based on input-output data with sector aggregation, it is not possible to drill down into specific material types or locations. However, we can make inferences about the likely types of materials this includes. For dairy, this flow is expected to be dominated by packaging. The second-largest plastic product consumer in the region is road transport. This flow likely includes logistics products such as pallets and pallet wrap.

Unlike metals, plastics recycling tends to rely on incentives. The average recycled content of plastic packaging is in Australia only 4% (APCO, 2021), showing there is significant potential for increasing the use of recycled materials on the input side – particularly through packaging in dairy products, but also within other sectors such as road transport and automotive repair. Since plastic packaging is not necessarily recyclable (such as soft plastics), incentives should focus on increasing recycled content. However, regulations limit the use of recycled content in some food-grade applications, so non-food grade products should be focused on, or FDA-approved recycled content food packaging.

Legislation to increase the recycled content in packaging has recently come into play in Europe, with several countries imposing punitive measures for when virgin plastics are favoured in packaging. In the UK, a tax is applied to plastic packaging manufactured in, or imported into the UK, that does not contain at least 30% recycled plastic (Government of the United Kingdom, 2021). Similarly, in Spain, a new tax has been employed targeting non-reusable plastic packaging, which applies a tax per kg of non-recycled content (EY, 2022). This indicates that measures to increase recycled content of plastics are best placed at a national scale.

Figure 13 – **Top 10 plastic-using sectors (excluding construction and trade) (kT)**



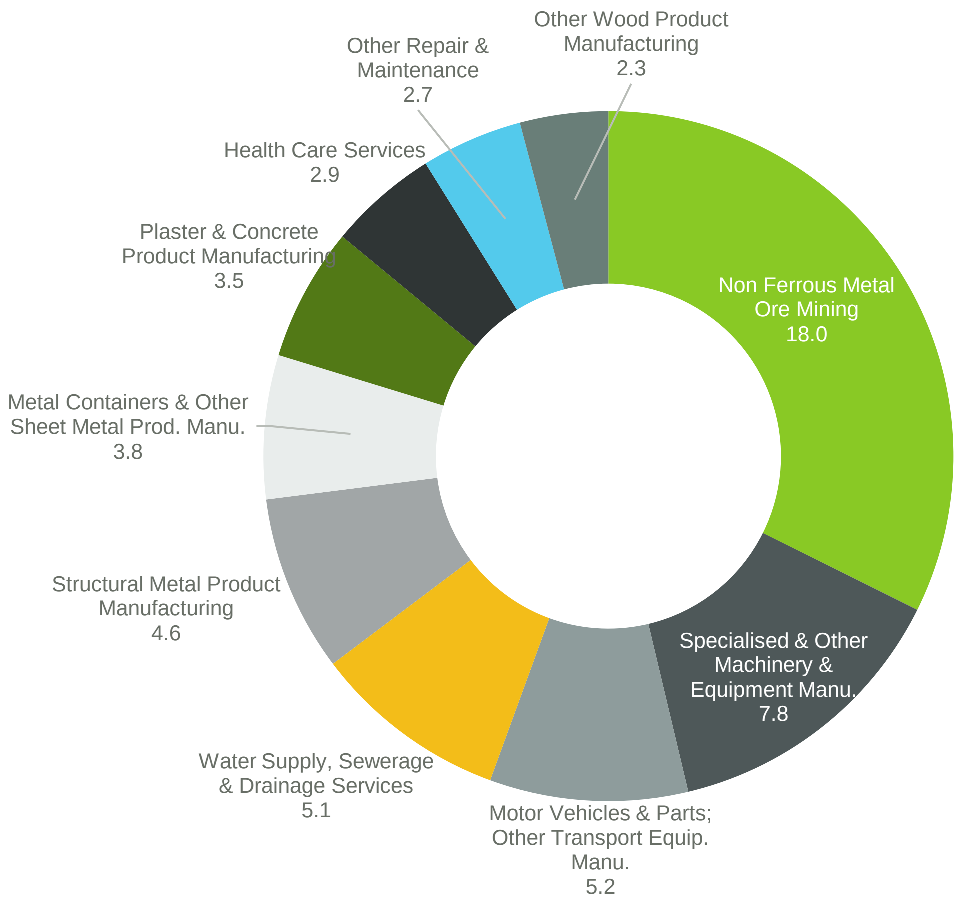
Consumer goods and manufacturing material flows

The analysis of metal products into industry showed that the largest industry consumer of metals is in non-ferrous metal ore mining followed by machinery and equipment manufacturing. From a circular economy perspective, metal recovery and recycling functions relatively well. Metal product manufacturing already uses recycled content where possible as it is cheaper than virgin metals, which in turn provides an incentive for collectors and recyclers to operate. The recycled content of metals into use in Australia is already at 37% (DCCEEW, 2020). Note that this differs from the recycling rate at end-of-life which is considerably higher. For this reason, circular economy strategies around increasing recycling of metal products at their end-of-life are likely to be less impactful than those focussed on closing the loop locally, getting more reused or recycled metals into assets.

An area to improve circularity of metals would be through ensuring recovery of streams that perhaps slip through the cracks, for example components in a product along with other non-separable and non-recyclable materials. This results in metals going to landfill if they cannot be separated. This issue can be addressed by improving uptake of design-for-recycling, which encompasses concepts such as mono-material design, recyclability of different materials, and labelling. Design-for-recycling is implemented at the product design stage and is influenced both by regulatory requirements related to design and production and education. Influencing circularity of metals through these measures are likely to come from national government or industry associations, rather than council-led initiatives.

Although flows from specific industries or locations could not be identified, the results from the circular scan do give a strong indication of areas to investigate further for potential circular demand of materials, as the largest flows are where the strategies can have the largest impacts.

Figure 14 – **Top 10 metal-using sectors (excluding construction and trade) (kT)**



Consumer goods and manufacturing material flows

In addition to the circular scan, key material flows were identified during the consultation workshops with stakeholders. The focus was on waste streams that are currently facing challenges in collection, recovery and identification of end markets. Material flows of concern identified included future end-of-life solar panels, wine bottles, silage plastics, tyres and mattresses. Some of these streams are more relevant to the Loddon-Mallee region considering the key industries, such as wine bottles and silage plastics. Others, such as solar panels, tyres and mattresses are not tied to the region specifically, and are expected to follow national trends in increasing circularity. These flows lend themselves better to national solutions rather than targeted region-specific solutions. For example, while the Loddon-Mallee region could be well-placed to be a circular hub for recovery of increasing end-of-life solar panels, it is expected that a national approach will be used to address this process given the technology required and value of materials.

Including **wine bottles** in a container deposit scheme would increase collection, though would be dealt with at the State level. Similarly, recycled content requirements are managed from State or Federal legislation. Focusing on reuse typically provides greater environmental and circular economy benefits than recycling, while also being suited to a local system. However, the benefits of reuse systems are highly dependent on the number of times a product is reused and hence should be maximised. This type of system may also be best suited to a focused area rather than the Region as a whole, to limit transport associated.

Beyond improving circularity, closed-loop solutions for wine distribution can also highlight local wines in the national market and increase tourism. Examples include refillable wine packaging, where customers bring their bottles back for reuse, or bulk wine solutions, where distributors source wine in reusable kegs. For instance Glou Wines in Melbourne provide wine in bulk packaging and are seeking ways to remanufacture kegs so that they can be used again, as is currently being done in Europe by OneCircle (glou, 2020); (KEYKEG, 2023).

Currently, silage wrap has limited recovery options and is often illegally burnt on-farm. Recycling systems for **silage wrap** are also emerging, including a Western Australia trial by Dairy Australia with the intent to develop a national scheme (Dairy Australia, 2020). Farmers collect the silage wrap, separating it from other plastics and other sources of contamination. A pick up service takes the wrap to recycling centres for processing into new plastic products.

From a more general perspective, improving circularity of consumer goods can be targeted through supporting second-hand markets. Repair and resale of used products, including homewares, clothing and appliances retains maximum value of products and keeps them in the economy longer, which displaces the need for new products. Challenges for the second-hand market in Loddon-Mallee are likely to be logistical and volume based, such as the costs of logistics are likely to be high relative to the cheap cost of new goods, potentially causing reused and repaired products to be more expensive than buying new. This area tends to need legislative support to operate. For example, in Sweden a tax break for repair services is used to encourage circulation of consumer goods (Skatterverket, n.d.).

Overall, the category of consumer goods and manufacturing presents significant challenges in data collection, so general understanding of material flows is limited. Filling data gaps in this area is a potential focus for future work, as direct data collection will likely be needed to improve material flow modelling.

Recommendations

1. Target difficult to recycle products which require local solutions

The Loddon-Mallee dairy industry could benefit by implementing a collection and recycling system for silage plastics

Wine production in the region presents an opportunity for a reuse system within the distribution stage.

2. Support industry to incorporate circular and recycled materials

Regional industry uses considerable resources to produce goods, especially metals and plastics. Using recycled materials – locally sourced where possible – could support supply chain resilience.

Table 4 – **Material flows for silage plastic and household glass**

Material	Tonnes available per year
Silage plastics	1,000
Household glass	9,900

Analysis of outputs: potential circular supply

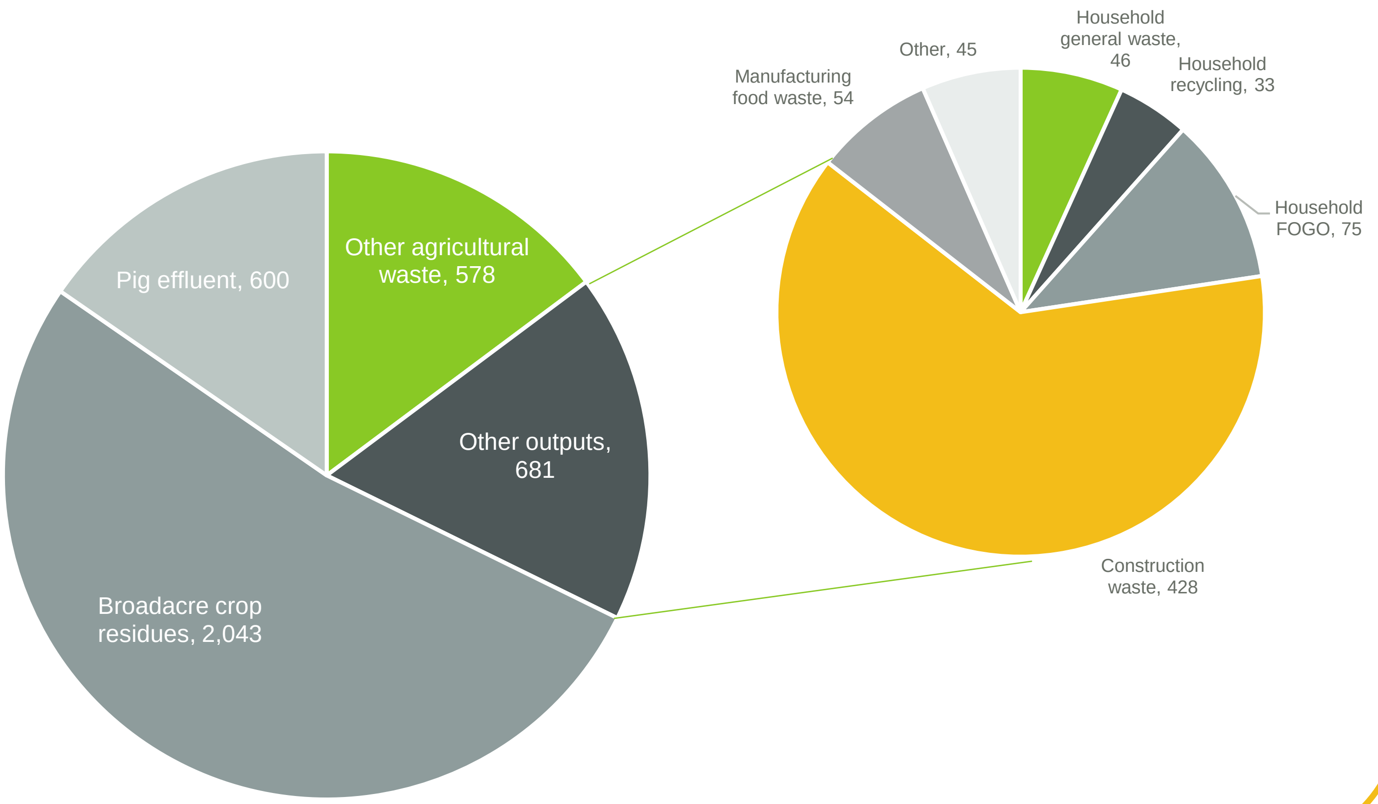
The circular scan identified key material flows within the Loddon-Mallee region, taking into account their applicability to create a supply or demand for circular materials. The circular supply findings are aggregated in Figure 15. It should be noted that this diagram includes all output flows that were assessed in the scan, but should not be considered a complete representation of all material outputs in the region. It is intended to provide an idea of scale and particularly to highlight the size of the agricultural residues in relation to other waste types.

Overall, the material output flows are dominated by agricultural residues, particularly broadacre crop residues. There is high potential here to increase circularity by finding uses for these flows while maintaining recommended amounts to leave on farm. This includes non-edible residues such as stubble, straw and leaves.

Aside from agriculture, the next largest source of material outputs is the construction sector. Since construction materials generally have pathways and the stock is accumulating, reducing life cycle impacts of construction becomes focused on building less and building less often, leading to interventions focused around increased utilisation and longevity. Household waste amounts are also included in the diagram to give an indication of scale.

In general, the circular economy strategies should focus on activities and material flows specific to the region, by taking into account the results from the circular scan. The aim here is to foster regional circularity for products and materials that are specific to the region and require local solutions. Other streams are part of more global circular strategies and may be less easily influenced through council-led initiatives. A combination of strategies is likely to result in the greatest benefits, as some activities lend themselves well to council- and business-led initiatives, while others require coordination or intervention from higher levels of government.

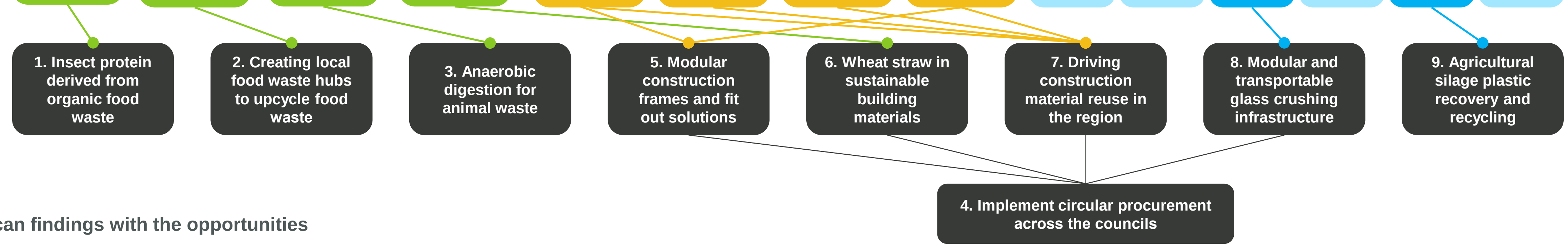
Figure 15 – **Primary outputs (circular supply) from the region (kT)**



Key findings from circular scan

Table 5 – **Key findings and target materials**

Sector	Organics	Construction	Consumer goods and manufacturing
Key Findings	The region is home to intensive agriculture and farming, resulting in high volumes of agricultural waste outputs and limited pathways to recover material. • Organic flows are dominated by crop residues, with other flows including produce waste and animal effluent. • There are pockets of intensive farming around different agricultural products such as dairy in northern Campaspe, wheat in Buloke and Loddon, food manufacturing (tomatoes, fruits and vegetables) in Echuca, and wine in Macedon Ranges. • High potential to increase circularity by finding localised or mobile solutions that create new uses or applications for these flows while maintaining recommended amounts to leave on farm.	High volumes of construction and demolition material flows driven by demand in commercial and residential construction sectors. • Material recovery across construction flows is quite high. • Material recovery is dependent on proximity to existing markets so having a better understanding of expected material needs could improve resource recovery. • There was less visibility on recycled content feeding into the sector. Using recycled content in construction presents an opportunity to increase circularity of the sector by driving demand for the recycling of these materials. • Increased circularity could also be achieved by extending the lifecycle of materials and products at their maximum value through application of circular design principles (modularity, design for repair).	Circular scan for consumer goods and manufacturing focused on identifying top industry users of plastics and metals, and looking at hard-to-recycle materials with relevance to the region. ▪ Circularity of metals could be improved by ensuring there are recovery streams for products containing metals. ▪ Biggest consumer of plastic in the region is dairy product manufacturing followed by road transport consuming pallets and pallet wrap. Increasing recycled plastic content in packaging across road and dairy industry would improve circularity of plastics. Stakeholders identified challenging waste streams including e-waste, mattresses and tyres. These include waste streams collected at councils transfer stations and which have no local material processing pathways. Challenges exist around both recovery and identification of end markets.
Potential target materials	Commercial and manufacturing food waste; Fruit and vegetables (tomatoes, grapes, olives); Animal waste; Cereal stubble including wheat and barley	Metals; Plastics; Concrete; Plasterboard	Mattresses; E-waste; Glass; Tyres; Silage plastics; Solar panels



Linking the scan findings with the opportunities

4

Circular opportunities

A circular opportunity is a set of interventions designed to extend the use and value of products and materials in the local economy and reduce the dependence on virgin, non-renewable materials.

Each opportunity aims to support the region's transition to a circular economy where waste is designed out, products are kept circulating at their highest value for as long as possible and natural systems are regenerated.

The process, findings and outcomes of the circular opportunity investigations are detailed in this section of the report.

Identifying the initial list of circular opportunities for investigation

At a workshop with the Stakeholder Reference Group in December 2022, the outcomes from the circular scan and sector analysis were presented with potential circular interventions for each sector identified. Case studies on circular product innovations and an initial list of circular opportunity ideas developed by the project team was also presented.

From here a high-level mapping exercise with stakeholders was conducted to identify potential circular interventions and ensure regional experience and challenges in this space was reflected into the initial list. For the purpose of the exercise, a circular opportunity was defined as *a set of interventions that extend the use and value of products and materials in the local economy and reduce the dependence on virgin, non-renewable materials.*

Once the shortlisted opportunities were defined, the stakeholder group collectively mapped each opportunity on the circular economy intervention hierarchy (Figure 16) to:

- ensure there are a diverse mix of circular interventions explored across a cohort of opportunities;
- encourage interventions that move products and materials up the value chain to extend the lifecycle within the local economy – beyond recycling.

The project team refined the shortlisted opportunities to ensure consistency around how each one was framed before the opportunity list was then validated with the client.

The following fifteen circular opportunities were investigated:

Organics

- Anaerobic digestion for post-industrial food waste
- Insect protein derived from organic food waste
- Upcycling food waste into value-added products
- Mobile manufacturing for on-farm produce waste

Construction

- Commercial reuse warehouse
- Implement circular procurement across councils
- Modular construction framing and commercial fit out solutions
- Wheat straw into sustainable building materials
- Micro factory options for building materials

Consumer goods and manufacturing

- Modular and transportable glass crushing infrastructure
- Glass bottle washing and reuse
- Localised e-waste recycling
- Closed loop packaging solution made from wheat straw stubble
- Silage agricultural plastics recovery and recycling
- Modular and transportable trye shredding plant

Desktop research and targeted industry consultation was conducted to investigate the scope, scale and impact of each opportunity. Questions that guided the investigations include:

- What is the key material, supply chain, end market problem this opportunity is trying to solve?
- Who are the key stakeholders involved?
- What is the potential circular economy intervention and/or technology required to solve the problem?
- Can the solution be scaled across regional supply chains?

Figure 16 – **Circular economy intervention hierarchy**

Smarter product use and manufacture	**Refuse**	Making a product redundant by abandoning its function or by offering the same function with a different product
	Rethink	Making product use more intensive (e.g. sharing and multi-functional products)
	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	**Reuse**	Reuse by another consumer of discarded product still in good condition, fulfilling its original function
	Repair	Repair and maintenance of defective product so it can be used with its original function
	Refurbish	Restore an old product and bring it up to date
	Remanufacture	Use parts of discarded product in a new product with the same function
	Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	**Recycle**	Process materials to obtain the same (high grade) or lower (low grade) quality
	Recover	Incineration of materials with energy recovery

Circular opportunity investigation and prioritisation

The data and insights gathered from the opportunity investigations were synthesised into opportunity profiles and disseminated to the Stakeholder Reference Group. The following industry stakeholders were consulted throughout the opportunity investigations:

- Agricultura Victoria
- Campaspe Shire
- City of Greater Bendigo
- COPAR packaging
- Dairy Australia
- Durra Panel
- EPR Enviro
- Fight Food Waste CRC
- Goulburn Broken Catchment Management Authority
- Macedon Ranges Shire
- Macedon Ranges Wine Association
- Mildura Development Corporation
- Mobius Farm
- Musk Lane
- Nutri V
- Pork Australia
- Regional Development Victoria
- Mildura Development Corporation
- X-frame

Opportunity prioritisation

A multi-criteria framework for prioritising opportunities was developed to:

- Help consider multiple factors relevant to provide a more comprehensive and balanced approach to prioritising opportunities.
- Provide a transparent and systematic approach to decision-making, so that decisions are made based on objective and well-defined criteria.
- Enable involvement of stakeholders in the decision-making process, to help incorporate their needs and perspectives.

Each opportunity was assessed by the project team against the following **impact** criteria:

- **Circular economy benefits** and where the opportunity was located on the circular economy intervention hierarchy.
- **Economic potential** to stimulate regional investment and create new jobs.
- **Impact and scale of opportunity,** targeted at a single business or material or whether it could be replicated or scaled across the region.
- **Environmental benefits** including landfill diversion or carbon emissions avoided.

Achievability was evaluated collaboratively with stakeholders considering the potential logistical, technological and commercial barriers to implementation in the region.

Defining the final list of circular opportunities

The results from the opportunity investigations and impact analysis were presented and tested with the Stakeholder Reference Group. The matrix scores were adjusted according to additional insights on the feasibility of implementation and the efforts and resources required to implement each opportunity.

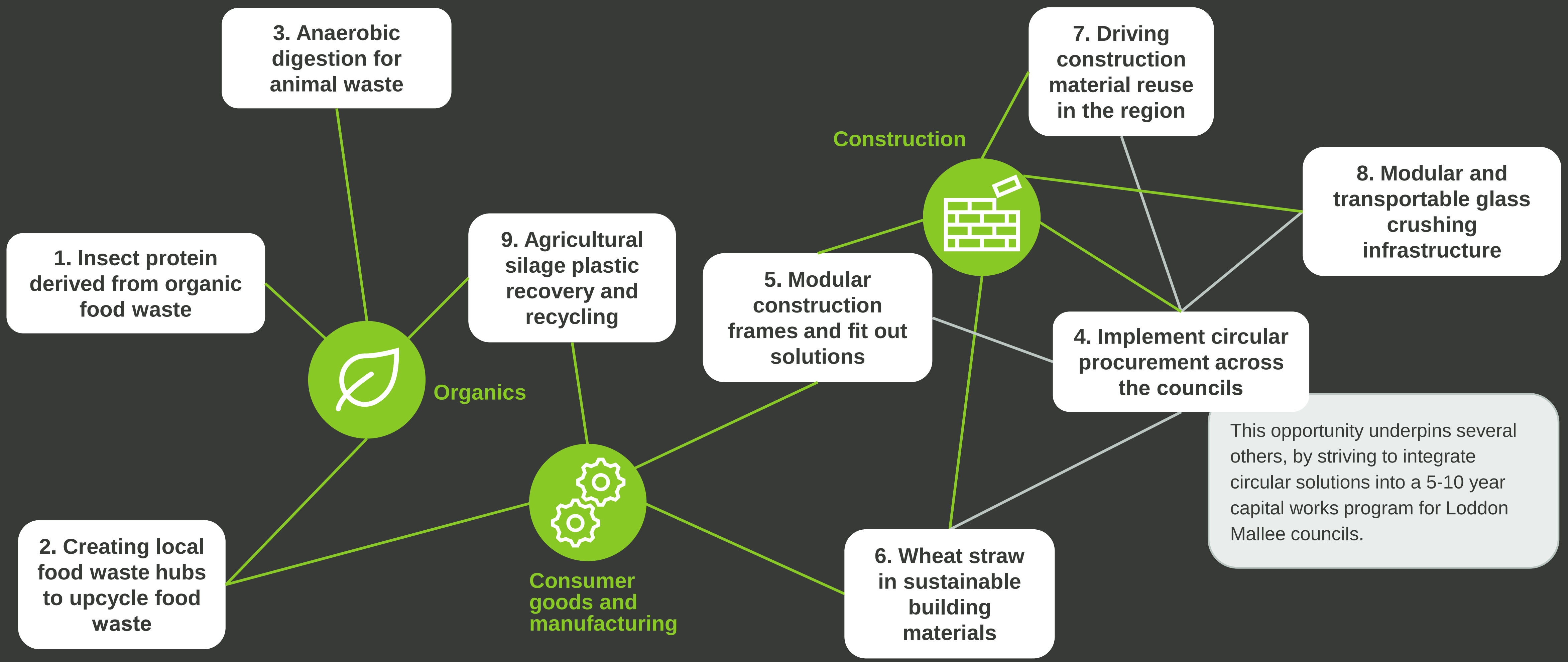
As an outcome of the workshop, the final list of circular opportunities was defined, reflecting the projects most likely to be implemented and to deliver circular, environmental and economic benefits to the Loddon Mallee Region.

The next step in the opportunity development was to quantify what the potential benefits look like for the region.

To inform the development of the circular opportunity profiles detailed in this section of the report, additional research and follow up interviews were conducted. Each opportunity profile contains information on the scope, potential benefits, technology and cost inputs, as well as details on the implementation pathway and actions for key stakeholders.

Figure 17 – **Prioritisation framework**

Nine circular opportunities investigated for the Loddon Mallee Region



Circular opportunity investigation and prioritisation

Opportunity benefit assessment

The opportunity profiles incorporate qualitative and quantitative analysis on the potential benefits if implemented in the region.

Interpreting the benefits considered;

- The potential carbon, economic and cost benefits of the opportunities identified are estimates.
- The assumptions and parameters used to inform the carbon emission modelling vary depending on the nature of the opportunity, as detailed in Appendix B.
- The general methodology for calculating the carbon benefit is focused on evaluating the net impact of implementing each circular opportunity. This is done by comparing the current situation to a scenario where the opportunity is implemented. Any additional impact sources are then calculated, and similarly any benefits are also accounted for.
- The data provides an indication on the potential scale of impact for each opportunity which may be used to justify further business case development.

Assessing the regional impact of the opportunities

The final list of opportunities vary in scale, scope and impact. While some target specific supply chain interventions such as agricultural plastics recycling, others are aimed at transforming produce or material value chains to generate new products and revenue streams such as wheat straw in sustainable building materials and food upcycling.

Certain opportunities sit over and above the more targeted ones, such as implementing circular procurement in local councils and driving construction material reuse in the region. Although the impacts of these opportunities were not able to be quantified within the scope of this study, their potential to reduce the use of virgin materials, keep material at a higher value for longer and reduce embodied carbon across infrastructure and construction, demonstrates close alignment to circular economy principles.

The diversity of opportunities reflects the wide range of economic activities and systems of production and consumption that the circular economy covers.

Table 6 provides a snapshot summary of the nine circular opportunities including a description, type and volume of feedstock it targets, the circular intervention used, the estimated carbon emissions avoided and potential economic benefits. For economic benefits, the number of dollar signs, signifies the scale of economic potential relating to regional investment, new job creation and new revenue streams.

In total the nine opportunities encapsulate **670,000t** of material and have the potential to avoid **418,000t** of carbon emissions in the region.

Snapshot of circular economy opportunities

$ Signifies the economic potential of the opportunity including regional investment, new job creation and new revenue streams.

Circular opportunity	Material input (p.a)	Circular economy intervention	Carbon benefit (p.a)	Potential economic benefit
1. Insect protein derived from food waste Scaling BSFL biodiversion technology to take food waste from commercial operations and manufacturing to create insect protein suitable for local stock feed.	70,000t of commercial + manufacturing food waste	Repurpose	**65,000t CO_2e avoided**	$$
2. Creating local food waste hubs to upcycle food waste Establishing a regional network of food waste hubs to transform surplus vegetable and fruit produce into value-added products suitable for food manufacturing and food retailers.	61,000t of fruit + vegetable produce waste	Repurpose Reuse	**9,700t CO_2e avoided**	$$
3. Anaerobic digestion for animal waste Establishing an anaerobic digestion facility to process animal manure into renewable energy to power waste water treatment facilities.	20,000t of pig manure	Repurpose Regenerate	**650t CO_2e avoided**	$
4. Implement circular procurement across the councils Developing a set of targets supported by a circular procurement framework to support councils individually and collectively maximise reuse, modular design and recycled material use.	N/a	Reduce	**9,500t CO_2e avoided**	$$
5. Modular construction frames and fit out solutions This opportunity will develop local manufacturing capacity to offer modular timber frames and fit outs for the construction sector in the region.	N/a	Reuse	**Not estimated**	$
6. Wheat straw in sustainable building materials Establish Central Victoria as a manufacturing hub of sustainable, low carbon construction materials made from wheat straw stubble to meet the growing demand from local, domestic and international markets.	527,000t of wheat straw stubble	Repurpose	**330,000t CO_2e avoided**	$$$
7. Driving construction material reuse in the region Shifting the local construction sector to a reuse model to reduce the use and transport of virgin material, allow improved material efficiencies, reduce carbon emissions and reduce waste.	N/a	Reduce Reuse	**Not estimated**	$
8. Modular and transportable glass crushing infrastructure This project is a joint procurement between participating councils to establish a mobile glass crushing machine to process glass waste into recycled crushed glass suitable for construction and roads.	9,900t of kerbside glass	Recycling	**245t CO_2e avoided**	$
9. Agricultural silage plastics recovery and recycling Local council partnership with Dairy Australia to support the expansion and acceleration of the silage plastic collection and recycling program in the region.	1000t of silage plastic	Recycling	**2,800t CO_2e avoided**	$
All opportunities combined	**667,900t of material**		**418,000t CO_2e avoided**	

Table 6 – **Snapshot of circular economy opportunities and benefits**

Opportunities to improve food systems

The following section summarises the circular opportunities relating to the organic material flows through agriculture, food and animal production sectors.

Three opportunities are explored;
#1 - Insect protein derived from food waste
#2 - Creating local food waste hubs to upcycle food waste
#3 - Anaerobic digestion for animal waste

Opportunity 1
Insect protein derived from food waste

Bioconversion from black soldier fly larvae (BSFL) has significant circular potential in creating valuable products from organic waste. The BSFL are housed in temperature and humidity-controlled units and fed macerated (mashed and fermented) food waste. The technology takes organic residues comprised of carbohydrates and protein and converts them to protein-rich insect meal which can be used for animal feed, aquaculture, and pet food. It can also process packaging contaminated food waste as the BSFL work around plastic packaging. Frass, a fertiliser byproduct of the bioconversion process, has been shown to improve soil resilience against climate change.

With successful operations across Europe (such as **Innovafeed**) and Asia (**Entobel**), BSFL in Australia is quickly following (see **Goterra**, **Bardee**, Veolia, **Mobius Farms** and **Arc Ento Tech**). Businesses across food manufacturing, the hospitality sector and, hospitals are already providing their waste as feedstock for BSFL. There are also opportunities on the horizon including engaging agribusiness for their pre-consumer waste. The scale, operational model, feedstock requirements and investment vary between different operations. While the technology is still relatively new in Australia, BSFL is a proven business model attracting investment, as shown by Bardee raising $5 million seed funding (Thomsen, 2021).

Across the region, the potential feedstock for BSFL is estimated at 70,000t/ year, including 16,000t food waste from commercial sources and 54,000t from food manufacturing. Agriculture waste has been excluded from this investigation as this waste stream is considered in Opportunity 2. With the right technology and logistics, this opportunity would create animal feed for sale to local end markets such as chickeries, piggeries and dairy farms as well as fertiliser byproducts to farms. Medium to longer term, BSFL could also provide protein for humans.

This opportunity is about scaling BSFL biodiversion technology to take food waste from commercial operations and manufacturing to create insect protein suitable for local stock feed.

How it would work

There are two main routes for BSFL bioconversion: on-site collection with modular facility or establishing a local processing hub. For an on-site collection, single businesses can directly hire or purchase infrastructure or local business collectives can work together to invest in on-site infrastructure. This is a de-centralised model using smaller scale modular units.

The second option includes setting up a centralised local processing hub so that material feedstock can be transported from satellite manufacturing plants or businesses and processed on one site.

A combination of on-site collection and centralised processing hubs can be developed across the region to adapt the solution by optimising co-location with larger supply streams (i.e. food manufacturing plants) and centralise collection of food waste from urban spaces to achieve the right scale and minimise transport where possible.

The solution would be implemented through companies with BSFL technology at strategic locations in the region collecting feedstock from food commercial operations and food manufacturers and distributing animal feed and fertiliser by-products to local farms.

Figure 18 – **Better Origin's X1 technology**

Case study - The world's first AI- powered insect farm

UK company, Better Origin X1 uses a combination of fly larvae and AI to turn food waste (fruit and vegetables) into chicken feed. The modular, shipping container sized insect farms are leased to farmers and stored on site.

The X1 processes the waste into larvae feed. The in-built AI oversees feeding and growth so the farmer does not actively monitor it. The larvae grow over a 7-14 day period until it's harvested and the insect-protein feed to livestock.

The machines are designed for medium and bigger farms. In the case of poultry the minimum flock size is 16,000. In 2021, the company signed a deal to supply 12 insect mini-farms to feed chickens at UK supermarket Morrison's egg farms. This project is projected to save 5,700t of CO_2e emission per year (Kamps, 2022)

One machine is designed to save 280t of CO_2e emission per year, processing 300t of food waste and prevents 5.6 hectares of deforestation as the insect protein becomes a replacement for traditional animal feed (Better Origin, n.d.)

Opportunity 1
Insect protein derived from food waste

Scaling BSLF across the regions

To scale the solution, four plants (~18,000t waste processed/ year/ plant) would be required across the region. Three plants would be co-located with the agri-businesses/ manufacturing plants in the region and one plant would be outside of Bendigo city to centrally process the region's commercial waste (Figure 19).

Supply side considerations: Co-location with manufacturing plant will give access to produce such as spoiled grain, lentils, oats, fruit, vegetable, meat and dairy.

Demand side considerations: Farms in the vicinity of each manufacturing plant, could access the animal feed (chicken feed substitute, pet food) and frass fertiliser produced through the bioconversion technology

Lead partner location

Selecting a range of lead partners to host and manage the technology will be a key factor in scaling the solution. BSFL technology use large volumes of energy for temperature control, so being able to power the technology with on site renewables is recommended.

Partners/logistics

Industrial symbiosis between food manufacturers and BSFL technology providers will create efficiencies.

Identify potential partners, set up partnership agreement, develop business case feasibility, identify trial site and proceed with implementation.

Cost/investment

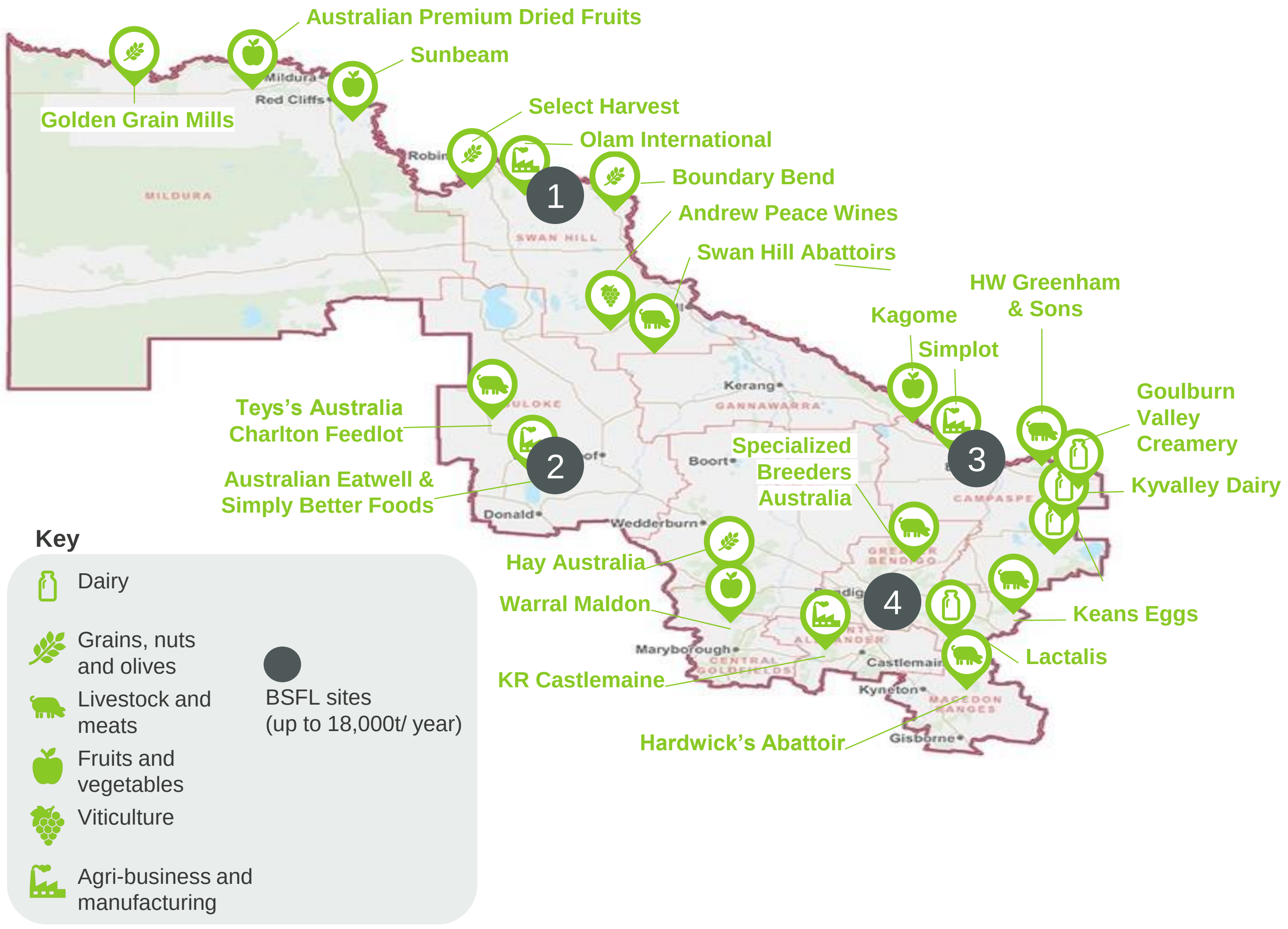
The expected capital investment for 70,000t food waste processing is between $60-90. This assumes that 4 plants will be set up in the region processing ~18,000t/ year).

Payback: 2 to 4 years.

Key stakeholders

Agriculture Victoria, Sustainability Victoria, local industry and farmers, BSFL technology providers, EPA, Venture Capital.

Figure 19 – **Agriculture and food manufacturing business map**



Opportunity 1
Insect protein derived from organic food waste

Benefits

BSFL are able to consume a wide range of organic food and other waste streams very quickly, so the technology can be scaled across the region to manage a variety of commercial and manufacturing food waste.

Even on a micro-scale (300t per year) the application of this technology delivers a range of cost and environmental benefits to farmers and industry. Medium scale projects have the capacity to process 300-1800t of food waste annually, diverting this produce from landfill and creating high value by-products that can be sold back into local agricultural and food supply chains. Given the volume of materials to process and the location of manufacturing plants, the opportunity is assuming the implementation of 4 medium scale facilities (18,000t per year each), delivering carbon benefits that equate to **65,000t CO_2e avoided**.

BSFL farming requires less land, water and resources than traditional animal feed protein production and waste management practices such as commercial composting. One key benefit is the potential GHG offset achieved through substitution of alternative source of proteins, which also has the added benefit of reducing animal feed input costs for farmers.

Circular economy

- 70,000t/ year material repurposed
- Design out waste, closed loop food waste system
- Moves food waste up the waste hierarchy, creating high value by-products including frass and animal feed

Economic potential

- Additional revenue in the region is expected to range between $40-60M per year and create in the order of 300 – 500 jobs (direct and indirect)

Environmental benefits

- 65,000t CO_2e avoided /year
- BSFL farming use less water, land and resources than traditional animal feed production.

Community benefits

- Collaboration between farmers, food manufacturing and food retailers
- Upskilling and training programs run for local staff

Critical areas of success

Establishing a collaborative investment or co-operative style business model between the relevant stakeholders could accelerate the implementation and achieve greater environmental benefits (industrial symbiosis). This disperses the risks and responsibilities and increases the level of engagement and opportunity for economical, social and environmental benefits.

BSFL farming is capital intensive to reach the scale and level of automation required. Understanding the manual labour inputs for the chosen technology and then factoring it into the project costs is a consideration. This also represents an opportunity to train and upskill local staff to support project implementation.

Next steps

Local council

- ✓ Engage with BSFL technology organisations to present the opportunity and gain interest
- ✓ Make introductions between manufacturers and food retailer association with BSFL technology organisations
- ✓ Support technology development through permit and land approvals (if relevant)

State government

- ✓ Educate farmers and producers on the process and benefits of bioconversion
- ✓ Advise and streamline regulatory pathway and approvals for establishing regional facilities

Industry

- ✓ Work with enabling organisations such as AgriFutures grow, universities, researchers, start ups, agtech investors and corporate to find innovative ways to implement BSFL their solutions at scale (partnership/ joint-venture models) to establish four facilities in the region
- ✓ Advocate to federal and state government for funding to support solution at scale

Opportunity 2
Creating local food waste hubs to upcycle food waste

In Australia a large amount of edible food is lost in the food supply chain before reaching the market. This includes an estimated 7-10% percent of fruit and vegetable biomass loss during the primary production stage (Juliano et al, 2019). Reasons including produce not meeting strict retail standards, low market prices, overproduction on farms and losses during harvest caused by weather, pests and diseases.

While a proportion of this food waste is recovered and used as animal feed or donated to food charities, the majority of produce will end up either being composted or left to rot on farms, resulting in a loss in value of the produce and a loss of revenue for the farmer. Food waste also has impacts on greenhouse gas emissions and water loss. In Victoria it's estimated that food waste generated from the primary production (on-farm, pre processing) results in 55kt of carbon emissions, uses 24 mega litres of waste and costs $218 million (Sustainability Victoria, 2020).

Within the region more than 61,000t of on-farm produce waste is generated annually including fruit and vegetables such as tomatoes, olives, grapes, stone fruits, potatoes, broccoli, pulses and legumes, avocadoes and nuts. Some of this waste is avoidable and can be addressed by improving production practices, storage and handling and developing new markets for imperfect or surplus food. For the unavoidable food waste other interventions are needed to improve the circularity of produce.

As discussed in Opportunity 1, one potential intervention, is processing food and/or produce waste into insect protein to be used as alternative source of animal feed. Another option is transforming unavoidable food waste into high value products and ingredients that can either be sold on the retail market or used in local food manufacturing.

Overseas companies that have demonstrated the potential in creating new food products from surplus waste include **Snact** and **Renewal Mill** in the UK, **Apeel** and **Barnana** in the US and **Agricycle** in Africa. Looking more locally, Victorian based food manufacturer **Nutri V** is turning vegetable waste into fibre and protein rich vegetable powders for sale in supermarkets and as an ingredient input for other food product manufacturing.

In recognising the potential for food additives, ingredients and other by-products to be produced locally from food waste, additional research on tomatoes, capsicums, wine grapes and potatoes is currently being conducted by Fight Food Waste CRC and the CSIRO.

Given the large amount of food produced in the region, there is an opportunity to establish local food waste hubs where processing and manufacturing technology could transform surplus produce into new products. These processes are more suited for surplus fruit and vegetable produce of which 61,000t are produced annually. The implementation of these hubs would benefit local growers to improve crop utilisation, reduce value loss of food waste and extend its life cycle across the food supply chain.

This opportunity will establish a regional network of food waste hubs to transform surplus vegetable and fruit produce into value-added products suitable for food manufacturing and food retailers.

How it would work

Based on the fruit and vegetable biomass host spot maps there are several locations where surplus produce could justify setting up on-farm or near farm operations to process or manufacture new food products. At this stage of the food supply chain, produce waste is usually uncontaminated, in a single stream and produced in higher volumes making it suitable for processing and manufacturing.

Processing solutions for adoption at the food waste hubs include:

- **fermentation** which can convert food waste into vinegars, alcohols and organic acids
- **extraction,** involving isolating valuable compounds from food waste to create protein rich food ingredients
- **drying and dehydrating** fruit and vegetables as a source of fibre, flavourings and colourings
- **extrusion** where produce is ground into a fine powder, mixed with other ingredients and cooked to produce edible snack products.

Opportunity 2
Creating local food waste hubs to upcycle food waste

Establishing a network of food waste hubs will require coordination and collaboration across the food production and distribution supply chain. The pathway to implementation will include identifying potential sites to host the hubs, confirming technological and resource requirements for each site, procuring and commissioning production and manufacturing technology and then managing production and product quality.

Food waste hubs will range in size. Based on existing food waste hubs in Victoria, a small-scale site similar to Nutri V's has capacity to process 8,000 tonnes of food annually and medium scale facility similar to Boundary Blend Olive Oil 's olive waste hub can process 20,000t. Extrapolating this data, we assume four small and one medium size food waste hubs would be needed to absorb the estimated 61,000t of fruit and vegetable produce waste in the region annually.

Partners/logistics

Primary growers would bring surplus produce to the sites for processing for a gate fee depending on the quality of produce, to be manufactured into new food products or ingredients.

Technology inputs include food storage equipment, packaging and labelling and processing equipment (dryers, dehydrators, mills, extruders, fermenter…). Food ingredients and by-products will then be transported to retail end markets or sent for additional food manufacturing.

Cost/investment

The capital investment estimation is calculated for four small and one medium scale food waste hub and are based on recent public and private investment into similar scale facilities in Victoria - Nutri V and Boundary Bend Olive Oil. The costs include purchasing, installing and commissioning equipment and other CAPEX costs including food packaging and labelling machinery.

$10-15 million of capital investment* is expected to be required to support the development of this opportunity.

Given the limited public information available, this investment figure is likely to be less than the actual costs.

Key stakeholders

Fresh produce suppliers, farmers, food manufacturers, food distributors, Agriculture Victoria, Fight Food Waste CRC, research partners.

What does this look like at scale?

Figure 20 below illustrates the potential sites for the four small and one medium scale food waste hubs proposed in this opportunity. The two criteria were used in identifying the potential sites, including a) the volume and concentration of produce waste within local government authorities also pictured within the spatial layers in the map; and b) the proximity of this produce to fruit and vegetable manufacturers.

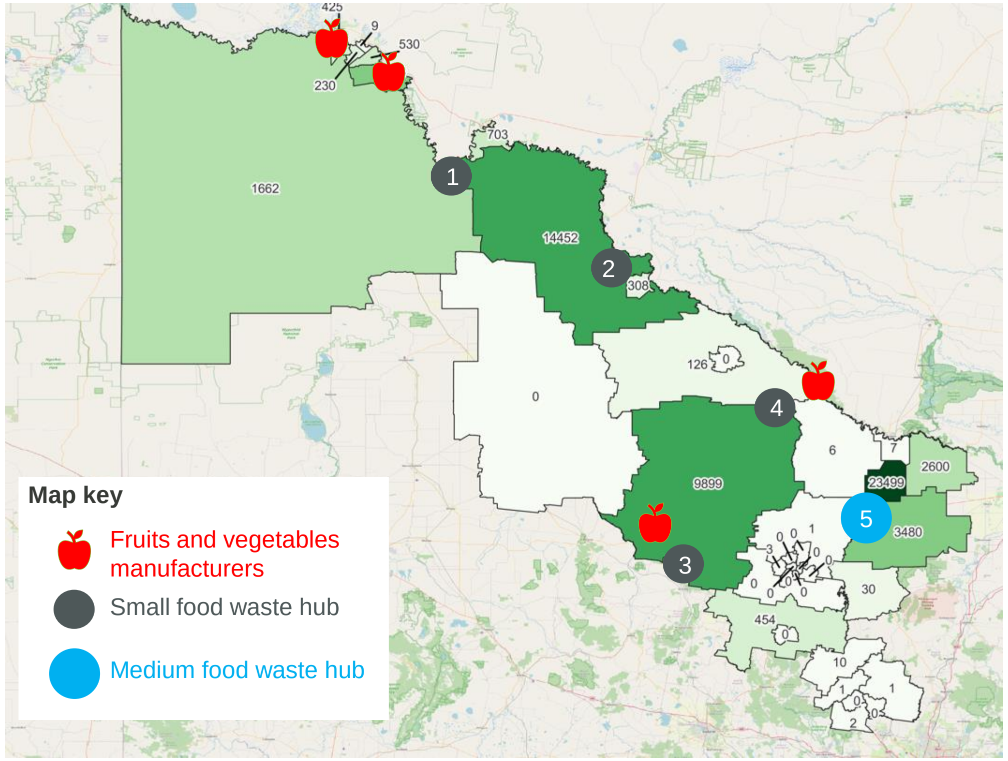


Figure 20 – **Potential food waste hub locations**

Opportunity 2
Creating local food waste hubs to upcycle food waste

Benefits

Creating new food products from upcycling food waste can offer significant benefits to local industry, essentially creating a new revenue stream from food waste and expanding the regions food manufacturing capabilities. There is a cost benefit for farmers and food producers as they get paid for supplying surplus produce that they would otherwise have to manage on site or send to landfill for disposal. For example, the current wholesale price for tomatoes in Australia ranges between $1170-4115/tonne (Selina Wamucci). If tomato producers were able to receive half the lower range price ($585/tonne) for selling on-farm tomato produce waste for upcycling, the additional revenue estimated for available tomato produce (35,000 tonnes) would be $40 million.

The food waste hubs are aimed at reducing the environmental impacts of food waste across the food supply chain and extending the life cycle of surplus food produce. Modelling conducted as part of this study identified that upcycling 61,000t of fruit and vegetable produce would result in a total of **9,700t** of carbon emissions avoided. This assumes that the upcycling of food waste avoided shallow burying of food on-farm and that the food waste hubs are powered by solar PV energy.

Circular economy

- 61,000t/year unavoidable food waste repurposed
- Extends the life cycle of food

Economic potential

- Creates new revenue stream for farmers from the excess produce waste. For available tomato produce waste alone, this is estimated at $40 million
- Local production hub will stimulate regional investment and create new jobs
- Additional revenue from the sale of upcycled food products and ingredients

Environmental benefits

- Reduces the environmental impacts of food waste between the primary production and processing and manufacturing stages of the food supply chain
- 9,700t of CO_2e avoided with 4 small and 1 medium food waste hubs capturing 61,000t of on-farm surplus food produce, assuming powered by solar PV energy

Critical areas of success

Establishing a network of food waste hubs to upcycle food waste will largely depend on whether there are viable end markets to purchase the food and ingredient by-products. Existing end markets for dried fruits and vegetable snack goods include supermarket retailers and independent grocers.

There is a much larger end market opportunity within Australia's food manufacturing sector to replace ingredients imported from overseas with local ingredients produced from food waste (such as fruit extract, acids and protein rich vegetable power)) to manufacture products such as ready-made meals, baked goods, spreads and condiments. Working with potential off-takers from the beginning of the process to ensure the product is developed to required specifications would support this.

Next steps

Local council

- ✓ Facilitate production hub development by collaborating with manufacturers and providing relevant planning and land zoning approvals

State government

- ✓ Develop market incentives to reduce surplus produce waste in the first instance*
- ✓ Provide tech start up funding like the Farm to Fork fund, to accelerate innovation of food waste upcycling
- ✓ Provide direct public funding to producers and manufacturers wanting to establish a food waste hub

Industry

- ✓ Support the development of new markets for imperfect surplus food
- ✓ Invest in food waste hubs, processing and manufacturing technology to upcycle produce waste into value added products
- ✓ Food manufacturers to increase demand for locally produced food ingredients and additives produced from food waste

**The EU and France have implemented regulations and standards to encourage sales of 'nonstandard' produce in fight against food waste*

Opportunity 3
Anaerobic digestion for animal waste

The Murray region is home to a high concentration of dairy farms, piggeries and animal farms. One of the main waste products generated from animal production is manure which left untreated is a significant source of methane and nitrous oxide – both harmful greenhouse gas emissions. Methane emissions from livestock digestion and manure management account for around 68% of the agricultural sectors' emissions which comprised 16% of Australia's total greenhouse gas emissions in 2022 (DCCEEW, 2022).

Animal manure is commonly managed on site in storage sludge ponds or via composting which can lead to risks around pathogen and soil contamination, odour pollution and also have negative impacts on soil fertility and health. Given its high organic content and nutrient risk composition, managed differently animal manure can be a valuable resource, used to produce biogas for energy production, fertiliser for crops and converted into compost.

One technology that is increasingly being used to convert livestock manure into renewable energy is anaerobic digestion (AD). AD is a process that occurs in sealed containers, known as digesters, where microorganisms break down organic matter in the absence of oxygen. High protein organic matter and biosolids such as food waste, human wastewater and animal manure are suitable inputs for AD (US EPA, 2023).

AD produces biogas and digestate:

- biogas can be used to provide heat, generate electricity or power cooling systems for local industrial processes
- digestate is a protein rich residual material which can be processed into soil fertiliser or put through a pyrolysis process to create biochar, a carbon rich charcoal.

Across Victoria, AD technology is being explored and adopted by water authorities as a potential pathway to achieve State Government mandated net zero emission targets. With the high concentration of pig and dairy farms, Australian meat industry bodies Dairy Australia, Pork Australia and Meat & Livestock Australia (MLA) have begun investigating the potential in partnering with a local water authority to establish an AD facility in Central Victoria.

This opportunity involves establishing an anaerobic digestion (AD) facility to process animal manure into renewable energy to power waste water treatment facilities.

How it would work

Similar projects such as Barwon Water's Colac Renewable Organics Network (CRON) demonstrate a potential implementation pathway. Barwon Water have partnered with Australian Lamb Company and Bulla Dairy Foods to build an AD facility to create biogas. See the case study for more information. Replicating this model will involve a partnership with Goulburn Valley Water, located in Campaspe Shire. Co-locating the facility on an existing wastewater treatment site and sharing existing infrastructure will also save costs.

Pig manure and end of pipeline milk waste are suitable feedstock inputs to wet AD facilities. While data on milk solids tonnages is limited, it's estimated that around 600,000t of pig slurry is produced annually from 270,000 pigs. AD facilities vary in size with average throughput ranging from 10,000 to 50,000t/year. This opportunity proposes one medium size facility of 30,000t/year which would be owned and operated by Goulburn Valley Water. Further feedstock composition analysis would be needed to identify the exact feedstock inputs.

Partners/logistics	Cost/investment	Key stakeholders
Commercial partnership led by Goulburn Valley Water with local pig and dairy farmers and industry associations. Financial, technological and regulatory considerations need to be defined in business case development phase. .	Business case development is estimated at $200-250k. The indicative capital cost of 30,000t/year facility is $13.7million (Sustainability Victoria, 2018). This is based on 2017 Sustainability Victoria's data and adjusted for inflation. Actual costs will depend on site and project specific factors.	Goulburn Valley Water, Campaspe Shire, Regional Development Victoria, Department of Energy, Environment and Climate Action (DEECA), EPA, local industry, Dairy Australia, Pork Australia, MLA, community stakeholders including indigenous and first nation groups.

Opportunity 3
Anaerobic digestion for animal waste

Benefits

Processing animal manure through anaerobic digestion demonstrates circular economy principles in transitioning to renewable energy and supporting regenerative agricultural practices. The potential carbon emissions benefit for a 30,000t/yr facility is estimated at **650t** carbon emissions avoided. This is calculated assuming only 20,000t of pig manure feedstock would be processed annually as the additional feedstock composition and quantities are yet to be established.

A project of this scale will also provide economic benefit to the region in the form of new jobs, upskilling and training. The Barwon CRON project for example created 17 construction and 45 ongoing jobs (Barwon Water, 2021). As the electricity generated is used to power large water infrastructure assets, it has the added economic benefit of driving down electricity costs for wastewater facilities and generating a new revenue stream for waste authorities from the sale of byproducts produced from the AD, including digestate.

Despite these potential benefits, processing animal manure through AD can represent a considerable cost to local farmers, especially if they're required to pay gate fees for disposing of animal waste. Financial incentives to farmers provided by industry or government would be needed to improve the financial feasibility of this opportunity for participating farmers.

Circular economy

- Create new value in 'waste product'
- Creating closed loop for managing agricultural waste

Economic potential

- Stimulate regional investment and create approx. 45 new jobs
- New revenue stream for water authority
- Increased waste management costs to farmers with subsidies or incentives

Environmental benefits

- **650t/**year of carbon emissions avoided from 30,000t/year facility
- Renewable energy generation and support net zero targets for water authorities

Community benefits

- Employment pathways, upskilling and training for local staff

Critical areas of success

Discussion on the potential benefits of AD needs to be balanced with the known challenges of implementing a project of this size, technical and commercial complexity. Key considerations to inform further project development include;

- Feedstock composition – managing biosolid outputs from mixing feedstock streams is a complex science, as not all animal sludge will be suitable feedstock. In identifying potential feedstocks, consideration should also be given to whether there are other viable, low carbon options for processing waste on site.
- Transporting feedstock – the complexity and cost of logistics to transport the waste to the AD site will be a key barrier to implementation. In identifying potential industry partners, priority could be given to intensive farms that generate high volumes of waste in a single spot.
- End market demand for AD byproducts – establishing off-take arrangements for either digestate fertilisers or biochar will determine the commercial feasibility of the project and will need to be considered early in project development.

Next steps

Local council

- ✓ Advocate to state government to provide funding and incentives to industry and farmers to improve animal manure waste management practices
- ✓ Provide appropriate land zoning and planning approvals for the AD site once selected

State government

- ✓ Provide funding to support further business feasibility
- ✓ Share learnings from Victorian Water authorities so that key project dependencies and risks are integrated into project scoping and design
- ✓ Provide market incentives to farmers to reduce barrier to entry

Industry

- ✓ Lead development of more detailed project feasibility and project implementation
- ✓ Provide incentives to farmers to participate in scheme and advocate to state and federal governments to provide public funding

Case Study – Barwon Water's Renewable Energy Network

The Colac Renewable Organics Network (Colac CRON) is an anaerobic digestion facility located in the south west of Victoria.

The project is a joint initiative between Australian Lamb Company and Bulla Dairy Foods to take organic trade waste diverted from landfill and convert it into biogas. At full scale the facility will produce 5.5 gigawatt hours of energy per year, enough to power the entire Colac wastewater treatment plant. This equates to a reduction of greenhouse gas emissions by 6,300 tonnes per year while also reducing the high energy costs of treating sewage and wastewater.

The soil waste leftovers derived from the process are converted into soil enhancers and sold to agricultural end markets

The project has led to the creation of 17 construction and 45 ongoing jobs as well as enabling Barwon Water to move towards achieving 100% renewable electricity by 2025 and zero net emissions by 2030 (Barwon Water, n.d.)

Figure 21 – **Colac CRON site**

Figure 22 – **Pyrolysis-delivered biochar**

Case Study – Wangaratta's green waste to biochar trial

In March 2023, the Victorian government announced the commencement of a six month trial program in Wangaratta, that will turn household sewage and green waste into biochar.

The project is being delivered by North East Water, the Rural City of Wangaratta, Gippsland Water and the Intelligent Water Network and will see biosolids from Wangaratta's wastewater treatment plant mixed with the city's green waste which will then turned into biochar in Melbourne.

A key objective of the trial is to assess the suitability of Wangaratta's waste streams for biochar conversion which if successful could lead to a local facility being build that can process large volumes of biochar for use in regional agricultural end markets.

The trial outcomes will also inform the planned expansion of Gippsland Water's organics recycling business in Duston's Downs, one of the largest circular economy operations in Victoria.

Project partners have invested $160,000 in the first stage of the trial. More info on the trial is available at North East Water.

Opportunities in construction

This section summarises the circular opportunities relating to construction and demolition material flows through residential and commercial construction sectors, local council procurement and capital works.

Four opportunities are explored;

#4 - Implementing circular procurement across the councils
#5 - Modular construction frames and fit out solutions
#6 - Wheat straw into sustainable building materials
#7 - Driving construction materials reuse in the region

Opportunity 4
Implementing circular procurement across the councils

Local governments operate significant capital works programs to develop and maintain new and existing infrastructure and assets. Across the nine councils, 2022-23 budget expenditure on capital works projects was over $280 million with $170 million allocated towards infrastructure projects. These projects including roads, footpaths, recreation and open space, buildings, drainage, infrastructure, and bridges utilise large volumes of primary and secondary materials. In the context of regional councils, material supplies are sourced from outside of the region and are transported large distances, increasing the cost and carbon footprint associated with these projects.

Over 95% of the materials required for roads is made up of five key materials: aggregates (29%), asphalt (27%), rock/bluestone (16%), sand (15%) and cement (9%) – and 27% of these conventional materials could be replaced by recycled material (Infrastructure Australia, 2023). This represents a significant opportunity for the region that can be harnessed by leveraging councils' significant buying power.

Barriers for councils in adopting more circular procurement practices include short term project planning and budget cycles, data and information on costs and benefits of circular materials and products, performance and environmental credentials of alternative materials, access to local suppliers and lack of price-competitive options.

Initiatives such as the Victorian Government's Buy Recycled Service under the Recycled First Local Government program (Sustainability Victoria, 2023) and the $2.7 million grant fund for local councils to trial the use of recycled materials in infrastructure projects provide enabling foundations. To scale circular and recycled content in infrastructure projects, councils can define ambitious targets and evolve their procurement practices and capabilities, work jointly to gain economies of scale and efficiencies. This significant transformative change is necessary to build up market capacity and maximise reuse/recycling of available waste materials.

This opportunity is to develop a set of targets supported by a circular procurement framework to support councils individually and collectively maximise reuse, modular design and recycled material use in their capital works programs.

How it would work

The circular procurement framework project would be delivered over a 12-month period to set circular targets across recycled content, reuse and low-impact materials (for example); and identify and implement relevant strategies to achieve these. It would entail taking council staff including procurement, engineers and project managers on a journey to build their circular economy capability, build upon existing processes and integrate tools and resources to make circular economy considerations easy, effective and efficient.

The project would involve reviewing current spend and future material needs (next 10 years) to confirm priority materials eligible for recycling content, opportunity for modularity and reuse, matching this demand forecast with local eligible waste streams, engaging with suppliers to evaluate how to maximise recycled material, reuse and modular construction in the region. Leveraging these findings, targets will be set, practical strategies and actions will be identified, tested and integrated across the procurement lifecycle. For example, using an evaluation tool to compare different material options (conventional, recycled, reused) against economic and environmental metrics will help inform decisions. In addition, new solutions through competitive dialogues and innovative partnerships between suppliers will be developed, to enable initiatives such as new infrastructure to produce recycled materials using local waste streams or disassembly methods to increase material reuse.

The procurement framework should be adaptable to work at multiple scale (single council to regional). The framework needs to ensure it caters for ambitious and transformative circular practices as the region builds capacity and the other proposed opportunities are being implemented.

Partners/logistics	Cost/investment	Key stakeholders
A working group of procurement practitioners across the councils should be established supported by a specialist consultant to build capacity, engage with other relevant teams and suppliers, co-create the targets and the circular procurement framework, drive implementation and share lessons learnt.	The main inputs for this project include time and resourcing from participating council staff. As well as the additional cost ($100k) for external support to drive market need analysis, inject circular procurement expertise and oversee the project delivery.	Nine local councils (procurement teams, engineers, project managers), Regional Development Victoria, Sustainability Victoria, Recycling Victoria, EcologiQ, suppliers

Opportunity 4
Implementing circular procurement across the councils

Benefits

This opportunity connects with a priority in the Loddon Mallee Regional Circular Economy Plan (RCEP) (DELWP, 2022) to map current and predicted material availability of secondary material markets and would support Opportunities 5, 6, 7 and 8 of this report, aiming at modular construction, sustainable building material and construction material reuse. The outcome will be to increase the uptake of recycled and/or sustainable materials and promote use of circular design and construction techniques in council infrastructure. If achieved this has flow on benefits to the local economy in that materials are being sourced from local suppliers as opposed to suppliers in Melbourne, resulting in reduced freight costs and associated transport emissions.

Building a picture of current spend, future material needs for councils, quantifying end market demand for priority materials, integrating targets and specifications into procurement will help attract public and private investment in material processing and recycling facilities and infrastructure, including modular, transportable and small-scale infrastructure for materials likely to feed into council procurement such a crumb rubber and crushed glass.

Using internal models for circular interventions such as reuse, design for disassembly, design for longevity, and design for materials efficiency suggest that a combination of these approaches can reduce the greenhouse gas impacts of the construction industry by 30-40%. Applied to the council spend on capital works in the region, this equates to a saving of approximately 9,500 tonnes CO_2e.

Circular economy

- Reducing reliance on virgin materials (27% replacement of roads materials into recycled content)
- Developing new end markets for secondary materials (reuse, recycled)
- Uptake of modular design and sustainable material

Economic potential

- Stimulate demand for local material suppliers
- In 2022-23 $170 million is being invested into local council infrastructure projects that could be directed towards optimising recycled and circular products

Environmental benefits

- Potential carbon savings from procuring local, secondary materials, modular design, sustainable materials in future projects – estimated 9,500t CO_2e avoided
- Support councils in scope 3 emission reporting

Critical areas of success

Developing a compelling value proposition for relevant members of councils to participate will be the first critical step in success. Council participation should be formalised and supported by council leadership with ongoing and regular engagement from the relevant council business units including procurement, asset managers, engineers, project managers, finance, sustainability and capital works. The success of the project will depend on the input from councils in terms of the breadth and depth of capital works project data gathered and buy in from engineers at council to design-in recycled content and circular materials/ designs into capital works projects. This can only be enabled by standards and specifications that allow for use of recycled content. State government agencies such as VicRoads and Department of Transport play a critical role in reviewing and updating existing standards and specifications to support these outcomes.

Next steps

Local council

- ✓ Confirm council participation and identify key internal contacts
- ✓ Review and update council procurement policies and targets to support circular economy outcomes
- ✓ Commit and embed circular and recycled material and product innovation across 10-year capital works programs through competitive dialogue

State government

- ✓ Legislate governmental 'recycled first' policy with targets
- ✓ Investment for regional processing plants for suppliers to support recycled material access
- ✓ Leverage the circular procurement framework for state level infrastructure projects in the region
- ✓ Continue to update supply side information on recycled materials and product suppliers that support local/recycled end markets

Industry

- ✓ Local contractors to support use of products and suppliers using recycled materials
- ✓ Work with local councils to guide where in project life cycle recycled materials needs to costed and integrated into project design
- ✓ Develop new partnership and delivery models to offer circular solutions

Opportunity 5
Modular construction frames and fit out solutions

The construction sector is a highly **resource-intensive** sector in the Loddon-Mallee Region. While the C&D recycling rate in Australia is close to the 80% waste recycling targets, there is a significant opportunity to implement higher value solutions such as reuse as well as closed the gap on the remaining ~20% by mass of C&D waste going to landfill in 2022. With the rollout of Recycling Victoria, the Victorian Government's 10-year circular economy action plan (State Government of Victoria , 2023) a shift to circular solutions in the construction industry is necessary.

Modular construction frames and fit outs can be prefabricated offsite and are a maturing solution that could help meet the needs of the region's growing construction sector while addressing its most pressing problems – high demand for virgin materials and high waste disposal costs. In addition, prefabrication minimises waste generation as only what is necessary is constructed. Meanwhile, modular construction frames are designed in such a way that they are easily disassembled and fully reusable at end-of-life, compared to traditional options that would have to be demolished and replaced. Houses built using modular frames are also flexible and can be expanded or scaled down as necessary.

Modular construction frames also provide the advantage of **faster construction times**, since only assembly is required on site. In regional locations, where skilled tradespersons (such as carpenters, electricians, and tilers) may be difficult to source locally, modular construction is an attractive option. Additionally, modular construction is typically unaffected by poor weather conditions as they can be constructed in warehouses and generates less on-site construction waste.

This opportunity aligns with various priorities and actions that were pinpointed in DELWP's Loddon Mallee RCEP (DELWP, 2022). These include developing end use markets for recycled content and materials and improving behaviour in industry and customers to adopt circular products.

Prefabricated timber frames are well established and already highly utilised in the Loddon-Mallee and Loddon-Campaspe regions. The point of difference being that modular frames and fit outs are designed for disassembly, and thus, fully reusable at end-of-life. To support this opportunity, local manufacturing capacity would be developed to offer modular timber frames and fit outs for the construction sector in the region.

The environmental benefits of modular construction frames and fit outs are further exemplified when choosing sustainable building materials, such as timber (preferencing local sources). Choosing timber frames for an average house can remove around 20 tonnes of CO_2e from the atmosphere (New Zealand Forest Owners' Association, 2020), some of which may become sequestered in the long term. On the other hand, traditional building materials such as concrete and steel can add up to 24 tonnes of CO_2e into the atmosphere per house (New Zealand Forest Owners' Association, 2020).

Modular construction reduces the use of virgin material, supports flexible design and reuse, minimizes waste, accelerates construction time and achieves greater carbon emission reduction when using sustainable building materials.

Case study: There are existing solution providers that offer modular frames and fit outs using certified sustainable timber, such as **Xframe**. Having successfully delivered several pilot projects in Australia and New Zealand, XFrame is now quickly approaching broad market release. When the solution has fallen outside of standard design scope, Xframe worked with engineers to provide State/Territory specific sign-off documentation (Xframe, n.d.)

Figure 23 – **Xframe demonstration, South Australia**

Opportunity 5
Modular construction frames and fit out solutions

How it would work

This opportunity involves the developing local manufacturing capability to produce modular construction frames from timber. One of the first steps would be to conduct a market sizing analysis to understand the total addressable market for this solution to understand the scale of the opportunity. In addition, this study can include an evaluation of social and economic benefits for the region to build the case for change and receive support from state / federal government to stimulate this market.

To stimulate the market, the region could advocate to Victoria State to integrate modular construction frame and fit out solutions requirements in the $5.3B Big Housing Build funding program, which would be a great catalyst to support the market in the region (**City of Greater Bendigo**, 2021). As a starting point, a short-term 'trial' could be conduct to understand the applicability and if benefits are demonstrated, it could be scaled across the entire program. This work would be connecting the circular procurement framework developed by councils to also support modular design in local housing development.

Prefabricated timber frames are already established and highly utilised in the Loddon-Mallee and Loddon-Campaspe regions and can evolve towards modular construction. The Big Housing Build funding program specifying requirements for this type of construction would accelerate the adoption of these practices by current local manufacturers and/or attract manufacturers with successful track-record in Australia to the region.

Developing communication campaigns and local / regional engagement with the sector would be a valuable activity to build awareness and educate the value chain about alternative approach to construction and disassembly.

Councils could join forces to leverage and promote state level funding mechanisms, such as the Circular Economy Business Innovation Centre (CEBIC) innovation grants offered by Sustainability Victoria (CEBIC, n.d.) for existing and/or new manufacturers establish this capability in the region.

While Xframe does not seem to have faced barriers of entry related to policy and standards in Australia and New Zealand, local and state regulations could be updated to incorporate targeted incentives supporting modular design and construction.

Partners/logistics

Local and national businesses across the value chain (sourcing of raw materials, manufacturing, transports and logistics, builders and contractors).

Getting the logistics around timber supply right will be important to ensure positive environmental and economic outcomes. Timber sourcing and will significantly impact on the project’s success.

The Victorian government has committed to planting 16 million trees over the next 10 years through the Victorian Forestry Plan, which includes timber sources that are suitable for this opportunity (DJPR, 2021). This will help provide security for the long-term supply of timber for the developed facility.

Local mass-engineered timber manufacturer Xlam could be another key partner in developing the supply chain around this opportunity.

Cost/investment

Expected investment around this project includes:

- $100K-150K for market sizing, economic and social impact assessment
- $50K education and engagement campaign with relevant industry stakeholders
- $50K regulatory and policy review to develop additional incentives
- $50K-150K state grant funding or incentive to attract and support capacity building in the region

Key stakeholders

Nine local councils, Regional Development Victoria, Sustainability Victoria, local builders and contractors, potential investors, manufacturers, Victorian Building Authority (VBA), local residents

Opportunity 5
Modular construction frames and fit out solutions

Benefits

Leveraging modular construction techniques for frames and fit out solutions will generate multiple benefits related to efficient material use, carbon emission reduction, reduced waste and local jobs creation. Modular light-weight timber frame construction system such as Xframe, can use 30% less material than standard timber wall framing, is carbon negative and rapidly recoverable. Embedding these practices in programs such as the Big Housing Build have the potential to deliver economic, social and environmental benefits at scale and drive market transformation in the region.

Circular economy

- Designed for disassembly and fully reusable at end-of-life, which will increase reuse and recycling rates for the sector in the region
- Prefabrication offsite minimises the amount of waste generated

Economic potential

- Diversion of C&D waste from landfill in the long term
- Potential carbon sequestration from using timber, depending on end-of-life of timber products

Environmental benefits

- Diversion of C&D waste from landfill in the long term
- Potential carbon sequestration from using timber, depending on end-of-life of timber products

Community benefits

- Access to homes that can be expanded or reduced easily (especially useful for growing families)
- More freedom to renovate buildings or homes frequently without waste generation

Critical areas of success

The first step for success is to advocate to state government to integrate modular design and construction requirements into programs such as the Big Housing Build.

Another area is facilitating builder uptake. Modular solutions providers identify builder uptake as the single largest barrier to success. They attribute this to builders' unwillingness to learn, since the techniques are easy to teach and do not require a specialised set of skills. Councils and state government will need to assist by encouraging behaviour changes in the local construction sector that may be achieved through incentives or outreach programs.

Next steps

Local council

- ✓ Confirm council participation and identify key contacts within council to engage with state government
- ✓ Council-led engagement campaigns to encourage builder uptake
- ✓ Procure modular products within council construction projects

State government

- ✓ Integrate modular design and construction requirements into development programs such as the Big Housing Build
- ✓ Provide grant funding support capability building and attract investors/ manufacturers in the region

Industry

- ✓ Local manufacturers to expand their capability to modular frames
- ✓ External manufacturers to invest in the region
- ✓ Builders and contractors to get 'on board' with the technology

Opportunity 6
Wheat straw in sustainable building materials

Wheat straw stubble is the portion of the wheat plant that remains after the grain and above ground plant material of wheat has been harvested. Across the region, approximately 527,000t of wheat straw stubble is available annually, after accounting for a sufficient amount to be left on the farm for soil health purposes. The material is commonly bailed and sold as animal feed, plowed on farm to fertilise soil or burnt. Although not as common as it used to be, grain growers have partially relied on burning stubble to manage weeds, diseases and reduce biomass to make sowing easier. In Victoria, stubble burning occurs for 21% of wheat crop residues (DCCEEW, 2020). This results in a loss of material value from the crop residues while releasing harmful particulate matter.

Given the amount of wheat straw stubble produced which is generally considered an agricultural byproduct, several opportunities were explored looking at ways to reuse this renewable resource as a material input into new products and applications. Existing Australian products include COPAR's compostable packaging and Ortech's Durra Panel – a compressed straw wall and ceiling panel used in commercial and residential construction which is manufactured in Bendigo.

As opposed to traditional plasterboard made from timber and steel, Durra Panel is manufactured from compressed wheat and rice straw sourced from local farmers around Bendigo. The panel production process requires no water or gas and produces zero toxic waste. It is 100% recyclable and biodegradable at end of life.

Products like Durra Panel demonstrate the potential of wheat straw stubble as a circular material input for low carbon construction products. Sustainable materials and products like this will be an important pathway for the building and construction sector in reducing the embodied carbon emissions of the built environment and moving towards a net zero future.

The opportunity for Central Victoria is to become a manufacturing hub of sustainable, low carbon construction materials made from wheat straw stubble to meet the growing demand from local, domestic and international markets.

Case study: Durra Panel can be customised for modular construction and is suitable for temporary, relocatable and emergency shelters. In the Sydney 2000 Olympics, 9km of Durra Panel was used to create the partition walls in the Media Centre. Following the completion of the games, the panels were deconstructed, shredded in a mulcher and used as compost in gardens in Sydney (Durra Panel, 2023).

Figure 24 – **Ortech's Durra Panels**

How it would work

Both supply and demand side interventions are needed to reach the scale of production needed to process the available wheat straw stubble in the region. In terms of supply, investment in research and innovation to diversify the range of products made from wheat straw stubble would support scaling production. Further applications outside of construction products could also be explored including wheat straw into packaging, furniture and into substrate for growing mushrooms. This work could be led and funded by the Grain Research and Development Corporation in partnership with local universities and industry and supported by Breakthrough Victoria, the Victorian Government's innovation accelerator fund (GRDC, 2023).

Once the wheat straw products are developed, investment to upscale production and establish new manufacturing facilities will be needed. State agencies such as Invest Victoria and Regional Development Victoria will play a critical role in attracting and facilitating investment into advanced manufacturing capabilities for this opportunity.

Stimulating end market demand for sustainable building products made from wheat straw stubble will also be a key feature in implementing this opportunity. Education and engagement with architects, designers, contractors, builders and consumers to build awareness of the environmental benefits of these products will be needed to support market adoption and expansion. Local and state government procurement can also play a critical role in driving demand for sustainable building products by specifying recycled content or low carbon products within project tenders.

Opportunity 6
Wheat straw in sustainable building materials

Partners/logistics

A joint collaboration between industry, government and research institutes, led by Australian Grain Research and Development Corporation.

Cost/investment

Investment into R&D needed to diversify the wheat straw product and application range is estimated at $10 million. This is based on Breakthrough Victoria's current innovation fund to identify circular solutions to solar PV technology.

Key stakeholders

Grain Research and Development Corporation, research institutes (La Trobe), Invest Victoria, Regional Development Victoria, Breakthrough Victoria, local and state governments, built environment industry (Masters Builders, Build Australia).

What does this look like at scale?

The amount of wheat straw available for reuse in this opportunity is 527,000t. This factors in the total volume of biomass stubble produced annually, minus the predicted amount left on-farms to maintain soil health.

The Ortech facility in Bendigo, pictured on Figure 25 has capacity to process 15,000t/year of stubble to produce 748,800 square metres of the Durra Panel product. To reach the scale of production needed to process available stubble, additional manufacturing lines and new facilities would be established:

- Two new processing lines at Ortech's existing facility to increase total throughput from 15,000t to 45,000t/year.
- A medium size facility (50,000t/yr) with additional two additional production lines added as demand grows. Total throughput 150,000t/yr.
- A large facility (150,000t/yr) with potential for one additional production line to be added. Total throughput 300,000t/yr.

The scope of this opportunity is contingent on factors including the development and commercialisation of new products made from wheat straw stubble and then market demand increasing to a point where additional investment is justified. As such, this is a pitched as longer term (10 years+) strategic opportunity for the region.

Figure 25 illustrates the volumes and locations of wheat straw stubble produced across the region as well as potential locations of manufacturing hubs. The manufacturing sites have been selected based on proximity to wheat producers and regional centres where products can be distributed to end markets.

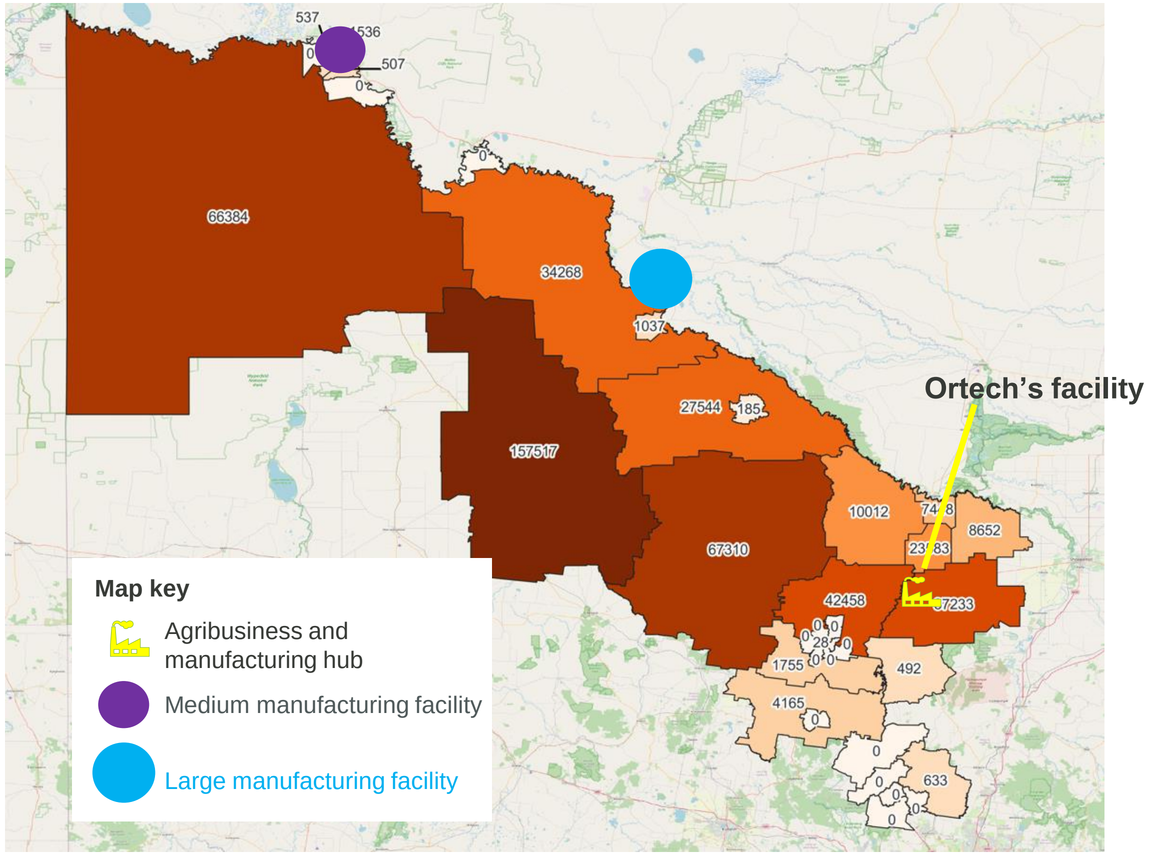


Figure 25 – **Map of wheat straw product manufacturing hub**

Opportunity 6
Wheat straw in sustainable building materials

Benefits

Potential carbon benefits have been modelled assuming that the region develops manufacturing capabilities that use all available wheat straw stubble as raw material for production. While building panels have been modelled as an example product, this would represent a radical expansion of existing capacity: over 30-fold. There is unlikely to be enough market demand to use all wheat straw for these panels, although if sustainable materials were to completely replace traditional materials it's not an unthinkable scenario. We would expect that with research and development support, the range of products would expand beyond panels. Accessing the available straw to products would have a significant environmental benefit, resulting in **330,000t** of carbon emissions avoided.

The significant expansion of advanced manufacturing capabilities across the region would stimulate investment into the region and result in new job creation. Based on the number of employees at Ortech's existing facility, 1,000 additional jobs could be created.

Additional revenue streams would benefit both farmers and the manufacturers. Variables around this opportunity are too uncertain for economic modelling at this early stage, however considering that straw is currently sold for $140-190/t in the region as a cheap fodder or bedding material product (Dairy Australia, 2020), we can estimate that the raw material is worth more than **$60 million**. The variability and demand around these existing markets makes it difficult for farmers to sell at this price at scale. This opportunity would unlock and increase that material value.

Circular economy
- Creating value added products from renewable resource
- Demonstrates circular design and material principles
- Creating closed loop from 'waste' material

Economic potential
- Creating around **1,000** jobs
- Additional revenue stream for farmers
- Revenue for manufacturers

Environmental benefits
- 527,000t of wheat straw stubble into low carbon building products would result in **330,000t** of carbon avoided

Critical areas of success

A significant uplift in demand for low carbon building materials and products is needed for this opportunity to reach its potential scale and impact. Left to business as usual, the uptake from industry will likely be slow due to market barriers such as price competitiveness and low market awareness. There is a role for State Government to accelerate this transition by creating regulatory or financial incentives for the built environment and construction industry to increase the use of circular materials and products in design and construction. For example, adapting the NSW's Government's Circular design guidelines for the built environment or mandating carbon emission reduction requirements in new buildings could drive demand for low carbon materials (OECC, 2023).

Next Steps

Local council
- ✓ Advocate to the Victorian State Government and economic development agencies around opportunity for Central Victoria to become leader in manufacturing for sustainable building materials
- ✓ Drive end market demand for sustainable building materials through procurement

State government
- ✓ Fund R&D to expand product range of construction materials made from wheat straw stubble
- ✓ Regional Development Victoria to invest into manufacturing facilities and hubs
- ✓ Create regulatory or financial incentives for industry to increase use of circular materials and products in design and construction
- ✓ Optimise the use of sustainable, locally manufactured products and materials in procurement

Industry
- ✓ Invest in product development to identify new materials and products made from wheat straw stubble
- ✓ Lead development and implementation of manufacturing hubs and explore interstate and overseas market expansion
- ✓ Industry bodies to run education and training for architects, designers and builders to improve uptake of low carbon building materials and products

Opportunity 7
Driving construction materials reuse in the region

While material recovery in the construction sector is high, some materials are at best recycled into lower application (such as concrete into aggregate). Reusing building components into commercial and residential development or renovation enables material to stay in use for longer at a higher value than recycling. A range of technical, logistical and financial challenges need to be addressed to increase reuse practices in the sector. On the demand side, guarantee of material volume and availability, alignment with specifications and cost are front of mind while on the supply side, removal cost and timeliness are the priorities.

Increased reuse of materials in the region will reduce the use and transport of virgin material, allow better material efficiencies, reduce carbon emissions, reduce waste and generate local economic benefits. To shift to a reuse first approach, a range of enabling conditions need to be created across the value chain to create demand while enabling a reliable and scalable supply.

The Facilitating the circulation of reclaimed building elements in Northwestern Europe project (FCRBE) aims to increase the amount of reclaimed building elements being circulated on its territory by +50%, by 2032. This program is addressing the significant challenges related to visibility, access to important projects and integration in contemporary building practices. 37 pilot projects have been conducted to assess how to efficiently extract and/or integrate reuse materials into the construction sector (Topalov et al., 2019).

Figure 26 – **Interreg intercountry initiative**

Shifting the local construction sector to a reuse model to reduce the use and transport of virgin material, allow improved material efficiencies, reduce carbon emissions and reduce waste.

How it would work

Leveraging existing regional reuse, reclaim and recycling facilities to source materials (such as tiles and bricks) and collecting data would help to test reuse on pilot projects, establish a material database and better understand current and future supply.

In addition, councils could run pilots to understand how to extract materials for reuse instead of recycling and disposal and how to re-circulate components into renovation and new developments. These pilots would test and formalise the changes required across supply and demand. Adapting procurement specifications to support using reclaimed materials and components will be required to guide designers and contractors.

- For "material extraction projects", councils would conduct an audit of what can be reused before deconstructing the sites (inventory) and assess reuse applications and paths.
- For "material reuse projects", councils would work closely with designers and suppliers to adapt their approach to material sourcing, design and construction.

This opportunity should be delivered in conjunction with a circular procurement framework. Feeding this information into a material database would provide easy access and visibility of service providers, material available and projects sourcing reclaimed materials and also measure environmental benefits. The learnings of the pilots will inform the circular procurement framework and identify improvement to existing reuse, reclaim and recycling facilities and related supply chains to scale the opportunity for construction material reuse.

Partners/logistics

Develop partnerships with reuse/ reclaim/ recycling facilities to source more systematically reclaimed materials.

Explore partnerships with tools such as ASPIRE to collect data on extracted and reused material, engage with Interreg to access learnings.

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Cost/investment

Medium to significant investment will be required to shift the practices in construction and demolition sector such as training professionals on techniques to audit, extract and reuse material, increase storage and logistics capacity and to adapt resource recovery service model to cater for reuse.

A forecasting study for reclaimed material potential could be achieved for around $50k

Pilots: margin cost, changes in procurement

Access to ASPIRE: $50k

Key stakeholders

Nine local councils (procurement, assets), local builders and contractors, designers, architects, salvage yards, demolition contractors

Opportunity 7
Driving construction materials reuse in the region

Benefits

Reuse extends the life of materials and components, which reduces virgin material extraction, use and transport and in turn reduces carbon emissions. Reuse also retains more value than recycling as it maintains the function of the material, component or product as initially designed to perform, avoiding downcycling for lower value applications.

While reuse has carbon emission savings potential due to avoiding processing of the waste into a secondary material, quantifying these benefits is premature. The calculations would be highly contingent on factors such as which elements are reused, logistics and efficiency of reuse. Implementing the opportunity will allow data collection on material types, volumes and carbon emission savings.

As reuse becomes common practice in councils' procurement, suppliers would build up their capability and capacity. Actively seeking reuse applications in the region can pave the way for other regions across Australia, which would create much broader benefits.

Circular economy

- Less virgin material extracted
- Material keep at a higher value and used longer
- Less waste generated

Economic potential

- Job creation in deconstruction, management/ storage and local transport of reclaimed material
- Extra revenue generated through the resale of reclaimed materials at scale

Environmental benefits

- Significant potential of carbon emissions reduction resulting from less virgin material extracted and transported

Community benefits

- Good use of taxpayer money through reuse of existing materials/ components in public assets
- Social value derived from a boosted local economy

Critical areas of success

- Mobilise and engage existing salvage yards/ reclaim business to access and/ or store reclaimed material.
- Get support and interest from designers, architects, builders to engage into pilots to integrate reclaimed material
- Shift mindset and build capability of demolition companies to experiment a deconstruction approach
- Develop tools, guides and training material to assist in the identification, extraction and integration of reclaimed materials and integrate into the circular procurement framework.

Next Steps

Local council

- ✓ Confirm council participation and define procurement requirements for reuse
- ✓ Engage with salvage yards
- ✓ Identify pilot projects for both extraction (deconstruction) and integration of reused materials

State government

- ✓ Develop a reuse policy and mandate percentage of reuse in the construction sector
- ✓ Provide grant funding to upskill local professionals on deconstruction and reuse practices
- ✓ Develop guidelines and tools for reuse, build storage facilities
- ✓ Participate in pilots for more scale

Industry

- ✓ Engage salvage yards, designers, builder, demolition businesses to better collaborate and respond to procurement requirements
- ✓ Engage with platforms such as ASPIRE to leverage their platform to build database and insights

Opportunities in consumer goods and manufacturing

This section summarises the circular opportunities relating to consumer goods and manufacturing material flows.

Two opportunities are explored:

#8 - Modular and transportable glass crushing infrastructure
#9 - Agricultural silage plastics recovery and recycling

Opportunity 8
Modular and transportable glass crushing infrastructure

The circular scan results identified that approximately 9,900 tonnes of glass is collected through the kerbside system annually across the nine councils. With limited glass recycling options available locally, large volumes of glass are currently being transported to Melbourne for processing. This is a significant cost impost to councils and represents a lost opportunity to re-circulate glass into regional supply chains and industry.

The feasibility of local glass processing has been limited by supply constraints including access to single stream glass. The commencement of Victoria's Container Deposit Scheme in 2023 and the introduction of the State Government's new standardised waste and recycling services, requiring all councils to establish separate glass collections by 2026, will address some of the supply side constraints, giving councils access to single-stream glass material.

While the intent of the separate glass bin is to maximise resource recovery of high quality material for glass to glass recycling, not all kerbside glass will be destined for this end fate. This is partly due to high cost of transporting glass out of the region to Melbourne for recycling which is estimated at between $30-40/t for the transportation alone. At the moment several of the regional councils including Bendigo and Macedon Ranges send their glass to ASQ Quarries for processing into sand.

Crushing glass for use in civil infrastructure and construction applications are other viable end markets for kerbside glass. Increasingly recycled crushed glass (RCG) is being used as replacement for silicas sand in the production on concrete or added as an aggregate into road base. The largest quantities of recycled materials that could be used to replace conventional materials in Australia are reclaimed asphalt pavement and recycled crushed glass - 24% of recycled material tonnage replacement (Infrastructure Australia, 2022).

Although these applications do not represent the optimal circular economy outcome for glass, they do reduce the demand for finite virgin materials (such as aggregate) which can also lead to a reduction in the overall emissions profile of infrastructure projects. Given councils will soon have access to a single stream of kerbside glass, there is scope to process some of this material locally for direct use across council projects.

This project involves a joint procurement between participating councils to establish a mobile glass crushing machine to process glass waste into recycled crushed glass suitable for construction and roads.

Case Study – Regional WA councils mobile glass crusher

In 2012, four councils in regional WA installed a mobile crusher to process glass collected through kerbside recycling into recycled crushed glass (RCG) for use in local civil construction applications.

The project is a joint initiative between the Roe Regional Organisation of Councils (RoeROC) a regional waste management group in Western Australia. Participating councils included Corrigin, Kondinin, Julian and Narembeen.

The mobile crusher processes glass collected from households and businesses through dedicated drop-off facilities in the region into recycled crushed glass (RCG). The RCG is then stockpiled and stored until it is ready to be processed by the shared mobile crusher. The crushed glass is used in local civil construction, primarily in road applications.

Since the project launched, more than 400 tonnes of local glass waste has been recycled each year (DER, 2015). More information on the project is available here.

Figure 27 – **Glass crushing machine**

Opportunity 8
Modular and transportable glass crushing infrastructure

How it would work

Participating councils would jointly invest to purchase a mobile glass crusher that would be moved around between council regions to process and crush stockpiled glass. There are a range of mobile glass crushers readily available on the market suitable for producing RCG (Jawscrushers, n.d.).

The Komplet Jaw crusher Mill Track M5000 glass crusher is suitable technology to process the amount of kerbside glass collected by the council (Direct Industry, 2023). It is the smallest tracked hammer mill on the market and can be loaded via ramps on a truck or trailed for easy transport. The machine can process up to 10t of glass per hour and produce crushed glass to 5-25mm size which is suitable for aggregate into road base and non-structural concrete applications.

Mobile glass crushing pilot projects have been trialled successfully in several councils across Western Australia (Quarry, 2020) and New South Wales (Sustainability matters, 2012). Councils must have a dedicated glass storage bay compliant with Environment Protection Authority (EPA) guidelines and relevant regulations on glass storage. Staff require additional to operate the machinery.

Partners/logistics

A memorandum of understanding would be established detailing supporting procedures for the shared use, management, maintenance, and insurances of the mobile glass crusher. Local road and asphalt contractors will also need to be engaged to ensure glass is produced to required specifications for use in local road projects.

Cost/investment

The capital cost of a mobile glass crusher is around $150k, depending on configuration and features.

Operational costs are estimated at $270k/year including machine maintenance (approx. $45k/year) and staff training and labor (0.3FTE per council at $80k salary).

If all nine council participate, this opportunity would require an initial investment of $22k and ongoing annual contribution of $30k per council. Transport and fuel costs are not included.

Key stakeholders

Nine local councils, Regional Development Victoria, Sustainability Victoria, VicRoads, local road and asphalt contractors, EPA.

Benefits

To understand the potential carbon saving benefits of this targeted opportunity, three glass scenarios were modelled. Each defines different end fates for the total volume of kerbside glass (9,900t), assuming that glass going to Melbourne requires 200km of transport and that glass into road base displaces gravel, and glass to glass recycling means glass batch and heat is avoided.

Scenario 1: glass to road base in Melbourne
↓
125t CO_2e produced with no emissions avoided

Scenario 2: glass into local roads
↓
245t CO_2e avoided

Scenario 3: glass to glass recycling in Melbourne
↓
4,970t CO_2e avoided

The modelling demonstrates that from a total carbon emissions profile perspective, sending all glass to Melbourne for glass-to-glass recycling is the optimal outcome. The high transport costs (approximately $40/t) means that councils including Bendigo and Macedon Ranges send their glass for local processing into sand (approx. $35/t). For a council with 2,000t of glass/year this costs $70k/year as opposed to $30k for operational costs for maintaining the modular glass crusher.

There is also additional cost offset potential into the road project if the councils are able to provide the glass sand they've crushed 'for free' to the asphalt contractor building roads, rather than paying $70/cubic metre for washed granite sand (ASQ , 2023). This will enhance the circularity of glass through local supply chains and reduce embodied carbon of future road projects.

Circular economy
- Developing new end markets for secondary materials
- Reducing reliance on virgin materials in construction

Economic potential
- $40k per year cost savings to council.
- Cost offset of $70/cubic metre of sand into future road projects

Environmental benefits
- 245t CO_2e avoided with all glass going into local roads

Opportunity 8
Modular and transportable glass crushing infrastructure

Critical areas of success

The success of this opportunity will be contingent on securing buy-in from enough councils to share the capital and operational costs for modular glass crushing infrastructure. The long-term viability of this opportunity will rely on councils' commitment to use recycled glass content in future council civil infrastructure and road projects. The opportunity to identify and pursue circular procurement frameworks and targets is explored further in Opportunity 4 of this paper.

Another critical area for success is ensuring the correct logistics are in place so that the processed RCG is channeled into council civil projects. Engagement with local contractors before the project commences is needed to ensure alignment of goals and expectations.

Next Steps

Local council

- ✓ Confirm council participation and begin project development
- ✓ Leverage data and analysis from *Opportunity 4 – implementing circular procurement*, to support more detailed business case development for glass crusher
- ✓ Work with contractors to identify opportunities to trial crushed glass in council capital works projects to validate end market potential

State government

- ✓ Provide grant funding to councils to either develop business case or for the purchase of a mobile glass crushing machine
- ✓ Promote use of RCG in local government capital works projects to support expansion of this end market opportunity

Industry

- ✓ Civil infrastructure and construction contractors to procure locally processed glass from councils

Case Study – Shoalhaven City Council, NSW

Shoalhaven City Council processes discarded glass into recycled crushed glass (RCG) at their dedicated recycling and waste facility in West Nowra. The facility, which began operations in 2021, processes reject glass fines from comingled Material Recovery Facilities to produce high quality glass sand for use in civil applications.

Fulton Hogan have received full approval to utilise the recycled glass sand produced by the facility in asphalt mixes for construction roads across the Shoalhaven region.

The project has produced RCG for local road works with council and in the Nowra Bridge Project for Transport for New South Wales (TfNSW). Including approximately 2,413,000 glass bottles for Shoalhaven road works and more than 5,000,000 glass bottles for the TfNSW Nowra Bridge project (Shoalhaven Council, 2021)


Figure 28 – **Glass crushing machine, West Nowra**

Opportunity 9
Agricultural silage plastics recovery and recycling

Around 90,000t of non-packaging agricultural plastics are generated each year in Australia, with only around 7% recycled (DAWE, 2021). This includes around 8,000 tonnes of waste farm plastics are dairy silage wraps and covers.

There are currently limited options for silage plastic collection and recycling largely due to the logistical challenges in collecting and transporting material from regional and rural farms to metro recycling processing facilities, as well as the associated costs with this process. As a result, silage plastics end up being landfilled, buried, or illegally burnt on farms, creating fire and biohazard risks for air and soil.

In 2021, the Federal Government awarded funding to Dairy Australia to design a national product stewardship scheme for farm plastics and to support the development of end-of-life solutions to farm plastics.

One of the first projects to be launched under this scheme is a silage plastics collection and recycling program which aims to support the Australian dairy industry reach its target to recycling 100% of silage wrap by 2030.

The Campaspe Shire has been selected as the region to launch the project due to the high concentration of agricultural production and farming including dairy, piggeries and other crops which generate silage plastic waste. Campaspe Shire also has some of the lowest drop off rates of silage plastics to landfill.

Dairy Australia estimate that in this region alone, 1,000t of silage plastic is generated every year with 60-70% burnt on farms. The collection system will launch in June 2023. It will be open to all farmers and will accept silage plastic only.

There is an opportunity for the local council to partner with Dairy Australia to support the expansion and acceleration of the silage plastic collection and recycling program in the region. This is the first initiative being launched under the Agricultural Plastics Product Stewardship Scheme and an important step in developing circular pathways for plastics otherwise ending up in landfill.

How it would work

In the first instance, Dairy Australia is looking for local partners to promote and champion the scheme to local farmers. Council transfer stations are also potential sites for plastic drop off and material aggregation points which may be needed as the scheme expands more broadly across the region.

To participate, farmers will need to purchase bulk bags, stands and bins to store and hold the plastics. The type of stand and bin will be specified as it must be compatible with the hook lift onto the collection vehicle. Although the upfront cost of these inputs is less that the cost to transport and disposal in a landfill, it will be a barrier to entry for some farmers.

The collection vehicles will then travel to the participating farms and collect the bulk bags filled with silage plastics which will be stored at a local aggregation. The silage plastic collected will be sent to a recycler in Clayton, Melbourne where it will be processed into a plastic pellet and used for remanufacturing into builder films and garbage bags.

Partners/logistics

The project will begin in the northwest of Campaspe Shire, an area surrounding Echuca and Wodonga with two local collection partners identified. Dairy Australia is seeking council support to promote the project to local farmers and through communication channels.

Cost/investment

Local councils, local farmers, industry peak bodies with members who could participate including Dairy Australia, Meat and Livestock Australia, Pork Australia, local collectors, plastic processor, silage wrap suppliers, Agriculture Victoria, Federal Department of Climate Change, Energy, the Environment and Water.

Key stakeholders

Local councils, local farmers, industry peak bodies with members who could participate including Dairy Australia, Meat and Livestock Australia, Pork Australia, local collectors, plastic processor, silage wrap suppliers, Agriculture Victoria, Federal Department of Climate Change, Energy, the Environment and Water.

Opportunity 9
Agricultural silage plastics recovery and recycling

Benefits

This project supports implementation of Australia's first Agricultural Plastics Product Stewardship Scheme which will be a key mechanism moving forward to deliver circular economy outcomes across the agricultural plastics supply chain. While the potential environmental benefits of this opportunity are relatively small to begin with, if successful the project could be expanded across the region to include additional plastic waste streams.

The economic and carbon emission modelling of this opportunity assume that:

- the project will divert 1,000t of silage plastic from landfill
- 60-70% of this silage plastic is assumed to be burnt under current practices
- cost savings reflect current waste level charges for landfill (EPA Victoria, 2022).

It's estimated that **2,800t** of carbon emissions can be avoided, including 1,950t avoided through prevented burning, 16t emitted due to additional transport and 890t CO_2e avoided due to recycling.

Although there will be a cost incurred for farmers in purchasing the silage plastic storage bags and bins, the potential savings from no longer sending plastic to landfill is estimated at $33,000.

Circular economy

- Provides a material recovery and recycling pathway for hard to recycle material
- Launch of product stewardship scheme is a critical step in developing circular pathways for agricultural plastics

Economic potential

- Collection process employs 2-3 local staff
- Reduction in landfill costs to farmers approximately $33,000 per year

Environmental benefits

- **2,800t** carbon emissions avoided from preventing plastic burning and recycling silage plastics.

Community benefits

- Collaboration between industry, government and farmers could lead to other circular economy initiatives

Critical areas of success

The short-term success of this opportunity relies on securing local farmer participation enabled by developing a compelling value proposition on the benefits to farmers bottom-line costs and to the local environment. Ultimately this project is about changing embedded waste management practices, so logistics need to be convenient, cost effective and supported by ongoing education and engagement.

The long-term viability of silage plastic recovery and recycling in the region and beyond will be contingent on the success of the incoming Product Stewardship Scheme for Agricultural Plastics. The scheme is currently funded by industry service bodies including Dairy Australia, MLA and Agri Futures. Once established, management will transition to silage plastic producers to run it, in line with commercial needs. The first 2-3 years of the scheme will be critical to establish the cost structures, secure market buy in, manage risk and build end markets to support its long term viability.

Next steps

Local council

- ✓ Partner with Dairy Australia and promote scheme launch to local farmers and networks
- ✓ Support ongoing education with farming community on good sorting and disposal practices to ensure clean, quality silage wrap is collected

State government

- ✓ Promote the project through Agriculture Victoria and Regional Development Victoria networks and channels
- ✓ Provide additional funding to support the initial start phase and of the Product Stewardship Scheme
- ✓ Encourage federal government to regulate extender producer responsibility on plastic waste across different industries and product applications

Industry

- ✓ Dairy Australia to seek funding opportunities from local and state government to provide farmers with rebate for the purchasing of bulk bin bags
- ✓ Dairy Australia to share and report back uptake and impact of the project to stakeholders
- ✓ Agricultural plastic producers to sign up to and support Product Stewardship Scheme

Other potential opportunities

Although not prioritised for the final list of circular opportunities, these options were identified during investigation, with results indicating potential future viability.

Localised e-waste recycling

While e-waste is generally captured under the national television and computer recycling scheme (NTCRS), materials are sent out of the region for processing. There is 3,300 t of e-waste in the region annually.

UNSW's Microfactorie™ takes e-waste and recovers plastics and metals (SMaRT@UNSW, n.d.). The alloys enable recycling of rare earth metals and minerals (traditionally there is no recycling option). Plastics can be reformed into filament for 3D printing or as feedstock for other manufacturing.

One Microfactorie™ for the region would be established close to e-waste collection networks, and to potential end users of the materials. At this stage Microfactories™ for e-waste are only in place at the University of NSW.

Closed loop packaging solution from stubble

Sector material flow analysis indicates 527,000t of wheat stubble is available in the region annually.

Australian packaging brand COPAR have developed a fully compostable packaging product made from reclaimed, renewable wheat straw pulp.

Straw is sourced from Australian farmers around their new manufacturing facility in Bathurst.

Looking to expand end markets into local hospitality and hospitals, schools, festivals and events and move into food manufacturing sector as a more circular replacement for berries and mushroom packaging. The technology can also be licensed, so if demand for product expands in region, potential for local manufacturing facility that uses locally sourced wheat straw.

Micro factory options for building materials

Waste such as contaminated glass, textiles, and mattresses create problems for disposal since they are traditionally difficult to recycle. At present, there are 500t – 2,500t of mattress waste per council collected annually and also 124t of C&D glass/yr that goes to landfill

'Green Ceramics' Microfactories™ are an emerging technology to transform these hard-to-recycle wastes into value-added products for use in buildings. These green ceramics are non-toxic, high performance bio-composites that can be used for various architectural and decorative applications. One Green Ceramics Microfactorie™ for the region would be established close to waste collection networks.

At this stage, a Green Ceramics Microfactorie™ is under construction in regional NSW.

Modular and transportable tyre shredding plant

Access to modular and mobile tyre shredding plant that can be moved around between council regions for use would address the expensive transport and processing costs by tyre recyclers and the problem of illegal tyre dumping.

Some councils are collecting 2000 to 3000 tyres on average per year and spending approximately $20k - $30k/yr each to transport and process these.

Mobile shredding units exist for passenger tyres, which are collected at transfer stations.

The shredded material is suitable for use in certain road applications (after being processed into crumb rubber), or to optimise transport to crumb rubber plants outside the region (which is only possible with fixed plant).

Glass bottle washing and reuse (loop system)

High volumes of glass bottles are used in the region, owing to the strong wine industry – the Macedon Ranges region alone consumes 2 million glass bottles annually.

These bottles are sent out of the region for recycling, which is expensive, produces high emissions, is water and energy-intensive, and focused on creating low-value end products. A local washing and reuse system could avoid these issues while preserving these materials at their highest value.

Successful glass bottle reuse models exist, although this has not seen an uptake in Australia due to a lack of locally manufactured machinery (fritz-kola, 2023; Loop, 2023). However, there is a local appetite for glass bottle reuse, with several industry stakeholders interested in creating this business model locally.

5
Other regional considerations

Transport and market barriers to closing material loops

A key challenge the region faces in accelerating its transition to a circular economy is the cost of transport and access to end markets. This is because high transport costs involved in the collection, sorting and processing of materials limits the economic viability of circular economy practices, making it more difficult for consumers, businesses and industry to adopt sustainable practices.

While this is a broad issue impacting the business case feasibility of all the circular opportunities explored, it is particularly accentuated for material and products generated and processed in small amounts locally.

Examples include e-waste, mattresses, textiles and tyres which are all currently collected by local councils and sent to Melbourne facilities for processing. Investigation was conducted to identify whether establishing a ‘material aggregation network and circular economy hub’ to manage these end of life materials could enable local recovery and recycling pathways.

Key takeaways from discussion with councils concluded:

- A material aggregation network already exists for these materials in the form of council transfer stations. Materials would still have to travel large distances across the region to a centralised processing hub.
- Identifying material collection and processing solutions is currently up to the individual council with limited coordination across councils to secure material off-take.
- The costs for council is increasing and competition to secure off-take for certain materials such as e-waste is high.
- Regional councils have access to collection services under national product stewardship scheme’s such as Paint Back and TechCollect but the collection costs are high. While some councils, including Bendigo are able to absorb the costs and offer this service to residents for free, others pass costs on, effectively disincentivising drop-off at Transfer Stations and impacting recovery rates.
- Proximity to end markets to off-take processed materials is still a significant barrier to creating circular material loops. Local end market opportunities could be explored for crumb rubber into roads but there is likely to be very limited demand from local manufacturers for secondary materials recovered from e-waste.

What is the solution?

Product stewardship schemes are a key mechanism in driving a circular economy as they place responsibility for managing a product's end of life with the producer or manufacturer and can create the right market incentives to enable reuse, repair and recovery. However ensuring national schemes are designed and implemented to address the unique challenges faced by regional supply chains requires joint advocacy by councils, state government and industry.

As outlined in *Opportunity 9 – Agricultural silage plastics recovery and recycling*, setting up product repair or material recovery pilots in regional areas is one way to test the viability of these schemes.

The Circular-Energy transition nexus

A critical assumption that underpins the shift to a circular economy is that all circular activities, from remanufacturing and recycling processes through to the movement of materials, will be powered by renewables. This narrative typically sees renewable energy as a generic foundation for a circular economy, and occasionally touches upon the need to consider renewable energy as any other industry. However, this narrative often overlooks the circular economy opportunities that could be unlocked by a transition to renewable energy, and conversely the prospects circular economy opportunities represent to the renewable energy transition. These next steps seek to paint a high-level picture of some of the opportunities represented by considering the confluence of circular economy and renewable energy opportunities, drawing upon best practice case studies across Australia and overseas, with local data and stakeholder insight across three project delivery phases.

The renewable energy perspective

There is a great push to decarbonise the electricity grid as swiftly as possible. The Victorian Government has recently committed to 95% renewable electricity generation by 2035, and 65% by 2030, with similar pushes across other states achieving high-levels of renewable energy penetration over the next decade (Vorrath, 2022). Although a vital component in reducing Victoria's carbon emissions, and enabling a truly circular economy, work to-date on the renewable energy transition has already highlighted constraints that are leading to 'missed opportunities' to use our existing renewable energy infrastructure. Specifically, the technical design of the electricity network and the National Electricity Market (NEM) is currently resulting in the 'curtailment' of electricity generation from solar and wind farms, either due to the physical grid not being able to physically accept more electricity OR due to financial signals (i.e. mismatch of supply and demand). Across Victorian solar farm projects, many of which are in the Loddon-Mallee region, this curtailment is estimated at around 21% (ARENA, 2022), representing a waste of potential renewable electricity and lost revenue to renewable energy projects. This ultimately impacts the lifecycle costs of renewables, slowing down their vitally important rollout. Future projections by the Australian Energy Market Operator (AEMO) suggested the level of curtailment for the entire NEM could remain high under a future of high renewable energy deployment, representing an opportunity to do something to avoid this curtailment and put such renewable energy to good use.

Through a Circular Economy lens

By looking at this curtailment of renewable energy through a Circular Economy viewpoint, two complementary opportunities arise:

- Locate regular and local users of this "wasted energy" i.e. using renewable energy locally to i) avoid physical grid constraints from exporting the energy and ii) provide a non-zero financial return for the generated electricity (the economic constraint).
- The localised use of otherwise constrained renewable energy also provides an opportunity for "cheap energy" if a user is flexible enough i.e. the generator wants to sell the electricity, but would accept a lower rate for the electricity (c/kWh) rather than receiving nothing by not being able to generate it in the first place. This cheaper electricity opportunity raises the potential for material recirculation processes that potentially have a high (but flexible) energy demand and are often prohibitively expensive to be setup in close proximity to areas of constrained renewable energy generation. A common example of this opportunity could be green hydrogen production, or electric arc furnaces for metal recycling, but could be extended to biorefineries and chemical plastics recycling facilities, to name but a few.

Expanding on these opportunities, renewable energy is typically generated in rural and regional areas, which are typically underdeveloped when it comes to energy-intensive industries, such as material recirculation, reprocessing and remanufacturing. By looking at potential localised users of existing and future renewable energy projects, there is the potential to improve the business case of renewable energy in the region AND develop industries that can support regional recirculation of end-of-life materials.

Future work

A quantified analysis of these complementary opportunities are outside the scope of this report, but their posing represents a chance for circular economy and renewable energy stakeholders in Australia to work together to explore it in more detail and start to quantify the opportunity both from a c/kWh (energy) and a $/t (materials recirculation) perspective. Together, these two industries could build upon their existing co-dependence as part of the sustainable transition and turn it into a virtuous cycle of synergies to reduce the cost of the transition to a renewably powered circular economy.

6

Next Steps

Building momentum and activating collaboration across councils and industry will be essential to make these opportunities happen

The Loddon Mallee Region is in a unique position to make transformative change at scale and demonstrate what regional leadership looks like. It has the potential to inspire change in other regions and accelerate the Australian transition to a circular economy. The circular scan has identified nine impactful opportunities across the organics, construction, consumer goods and manufacturing sectors to better use the current resources available in the region, reduce waste and carbon emission while creating jobs and social benefit for the community. These opportunities will either need to be led by councils, state government or industry. To turn this report into action, councils will need to build up momentum internally, across councils, with state government and industry.

Overall next steps

Local council led opportunities

- Implement circular procurement across the councils
- Driving construction material reuse in the region
- Modular and transportable glass crushing infrastructure
- Agricultural silage plastics recovery and recycling

- **Get local councils' leadership team onboard:** present the circular scan and opportunities to seek support and endorsement to integrate time and resourcing in upcoming budget and plans to
  - lead council specific opportunities (direct contribution)
  - socialise and handover the other opportunities to state government and industry (indirect contribution)
- **Develop an overall implementation and engagement plan:** clarify roles, responsibilities, timelines to launch the opportunities, within and across councils for both direct and indirect contributions to opportunities.

State government led opportunities

- Modular construction frames and fit out solutions – with strong demand from state
- Wheat straw in sustainable building materials

- **Get state government onboard:** present the circular scan and opportunities to seek support in:
  - creating the enabling conditions identified across all opportunities
  - leading the state government specific opportunities

Industry led opportunities

- Insect protein derived from food waste
- Creating local food waste hubs to upcycle food waste
- Anaerobic digestion for animal waste

- **Get industry onboard:** socialise the circular scan and opportunities with local industry stakeholders and key organisations to:
  - attract in the region to generate interest,
  - build on the existing positive engagement and leadership (e.g. Dairy Australia and Pork Australia)
  - enable collaboration/ partnership opportunities
  - 'handover' the opportunities back to the market.

Next steps mapped against enablers of change

Table 7 **– Summary of next steps for local council, state government, and industry, identified in the circular opportunities**

Opportunity		Developing end use markets	Improved infrastructure	Legislation, regulations or standards reform	Improved collaboration and communication	Behaviour change	Other key changes
1. Insect protein derived from organic food waste	Local Gvt	Make introductions between manufacturers and food retailer association with BSFL technology organisations		Support technology development through permit and land approvals (if relevant)	Engage with BSFL technology organisations to present the opportunity and gain interest		
	State Gvt			Advise and streamline regulatory pathway and approvals for establishing regional facilities		Educate farmers and producers on the process and benefits of bioconversion	
	Industry				Work with enabling organisations such as AgriFutures grow, universities, researchers, start ups, agtech investors and corporate to find innovative ways to implement BSFL their solutions at scale (partnership/ joint-venture models) to establish four facilities in the region		Advocate to federal and state government for funding to support solution at scale
2. Creating local food waste hubs to upcycle food waste	Local Gvt			Facilitate production hub development by providing relevant planning and land zone approvals			
	State Gvt		Provide direct public funding to producers and manufacturers wanting to establish a food waste hub	Develop market incentives to reduce surplus produce waste in the first instance. The EU and France have implemented regulations and standards to encourage sales of 'nonstandard' produce in fight against food waste		Provide tech start up funding like the Farm to Fork fund, to accelerate innovation of food waste upcycling.	
	Industry	Food manufacturers to increase demand for locally produced food ingredients and additives produced from food waste. Support the development of new markets for imperfect surplus food	Invest in food waste hubs, processing and manufacturing technology to upcycle produce waste into value added products.				

Next steps mapped against enablers of change

Table 7 – **Summary of next steps for local council, state government, and industry, identified in the circular opportunities**

		Developing end use markets	Improved infrastructure	Legislation, regulations or standards reform	Improved collaboration and communication	Behaviour change	Other key changes
3. Anaerobic digestion for animal waste	Local Gvt			Provide appropriate land zoning and planning approvals for the AD site once selected		Advocate to state government to provide funding and incentives to industry and farmers to improve animal manure waste management practices	
	State Gvt		Provide funding to support further business feasibility	Provide market incentives to farmers to reduce barrier to entry		Share learnings from Victorian Water authorities so that key project dependencies and risks are integrated into project scoping and design	
	Industry		Lead development of more detailed project feasibility and project implementation	Provide incentives to farmers to participate in scheme and advocate to state and federal governments to provide public funding			
4. Implement circular procurement across the councils	Local Gvt		Commit and embed circular and recycled material and product innovation across CAPEX project portfolio through competitive dialogue	Review and update council procurement policies and targets to support circular economy outcomes	Confirm council participation and identify key contacts within council to drive project forward		
	State Gvt	Continue to update supply side information on recycled materials and product suppliers that support local/recycled end markets	Investment for regional processing plants for suppliers to support recycled material access	Legislate governmental 'recycled first' policy with targets		Leverage the circular procurement framework for state level infrastructure projects in the region	
	Industry	Local contractors to support use of products and suppliers using recycled materials.			Develop new partnership and delivery models to offer circular solutions	Work with local councils to guide where in project life cycle recycled materials needs to costed and integrated into project design.	

Next steps mapped against enablers of change

Table 7 **– Summary of next steps for local council, state government, and industry, identified in the circular opportunities**

Opportunity	Stakeholder	Developing end use markets	Improved infrastructure	Legislation, regulations or standards reform	Improved collaboration and communication	Behaviour change	Other key changes
5. Modular construction frames and fit out solutions	Local Gvt	Procure modular products within council construction projects			Confirm council participation and identify key contacts within council to engage with state government	Council-led engagement campaigns to encourage builder uptake	
	State Gvt		Provide grant funding support capability building and attract investors/ manufacturers in the region	Integrate modular design and construction requirements into development programs such as the Big Housing Build			
	Industry	External manufacturers to invest in the region Builders and contractors to get 'on board' with the technology	Local manufacturers to expand their capability to modular frames				
6. Wheat straw in sustainable building materials	Local Gvt	Drive end market demand for sustainable building materials made of wheat straw through procurement		Advocate to the Victorian State Government and economic development agencies around opportunity for Central Victoria to become leader in advanced manufacturing for sustainable building materials			
	State Gvt		Regional Development Victoria to provide public investment into new manufacturing facilities and hubs that support opportunity implementation	Create regulatory or financial incentives for industry to increase use of circular materials and products in design and construction		Optimise the use of sustainable, locally manufactured products and materials in procurement	Provide R&D grant funding to expand product range of construction materials made from wheat straw stubble
	Industry		Lead development and implementation of manufacturing hubs and explore interstate and overseas market expansion		Invest in product development to identify new materials and products made from wheat straw stubble	Industry bodies in the built environment to run education and training to architects, designers and builders to improve awareness of and uptake of low carbon building materials and products	

Next steps mapped against enablers of change

Table 7 **– Summary of next steps for local council, state government, and industry, identified in the circular opportunities**

Opportunity	Stakeholder	Developing end use markets	Improved infrastructure	Legislation, regulations or standards reform	Improved collaboration and communication	Behaviour change	Other key changes
7. Driving construction material reuse in the region	Local Gvt				Confirm council participation and define procurement requirements for reuse	Identify projects to conduct pilots or both extraction and integration of reused materials	Engage with salvage yards
	State Gvt		Potentially provide grant funding to upskill local professionals on reuse practices, develop guidelines and tools for reuse, build storage facilities	Develop a reuse policy and mandate percentage of reuse in the construction sector	Participate in pilots for more scale		
	Industry				Engage salvage yards, designers, builder, demolition businesses to better collaborate and respond to procurement requirements		Engage with ASPIRE to leverage their platform to build database and insights
8. Modular and transportable glass crushing infrastructure	Local Gvt	Work with contractors to identify opportunities to trial crushed glass in council capital works projects to validate end market potential	Leverage data and analysis from Opportunity 4 – *implementing circular procurement*, to support more detailed business case development for glass crusher		Confirm council participation and begin project development		
	State Gvt		Potentially provide grant funding to councils to either develop business case or for the purchase of a mobile glass crushing machine			Promote use of RCG in local government capital works projects to support expansion of this end market opportunity	
	Industry	Civil infrastructure and construction contractors to procure locally processed glass from councils					

Next steps mapped against enablers of change

Table 7 – **Summary of next steps for local council, state government, and industry, identified in the circular opportunities**

9. Agricultural silage plastic recovery and recycling

	Developing end use markets	Improved infrastructure	Legislation, regulations or standards reform	Improved collaboration and communication	Behaviour change	Other key changes
Local Gvt				Partner with Dairy Australia and promote scheme launch to local farmers and networks	Support ongoing education with farming community on good sorting and disposal practices to ensure clean, quality silage wrap is collected	
State Gvt		Provide additional funding to support the initial start phase and of the Product Stewardship Scheme	Lobby federal government to regulate extender producer responsibility on plastic waste across different industries and product applications		Promote the project through Agriculture Victoria and Regional Development Victoria networks and channels	
Industry		Dairy Australia to seek funding opportunities from local and state government to provide farmers with rebate for the purchasing of bulk bin bags		Dairy Australia to share and report back uptake and impact of the project to stakeholders	Agricultural plastic producers to sign up to and support Product Stewardship Scheme	

Recommendations: the local councils should action all four policy levers available to drive circular economy in Loddon Mallee region

1 Mobilise

Visions and ambitions | Govern the transition | Convene towards action

- Identify circular economy champion across councils for each sector responsible to build momentum towards long-term change.
- Establish a network governance, involving a coalition of partners and transition brokers in the region to drive the change across the three sectors.
- Advocate to state government for policy changes, funding and active involvement to implement the opportunities.
- Ensure the opportunities are progressed in parallel across the sectors to maximise systemic change and impact.

2 Educate

Communications and awareness | Education and curriculum | Knowledge management | Research and development

- Socialise the opportunities, benefits and required changes to industry to catalyse change.
- Build the necessary skills and knowledge around the circular economy across industry to transition the organic, construction, consumer goods & manufacturing sectors in the region.
- Increase the overall levels of awareness in the community to shift consumption patterns.
- Connect with researchers and universities to drive regional innovation and build capacity/capability.

3 Manage

Spatial planning | Public procurement | Infrastructure | Asset management

- Integrate circular procurement practices across councils, with a particular focus on reuse, modular design and construction and recycled content to enable the opportunities identified in the construction and consumer goods & manufacturing sectors.
- Review asset management practices to extend lifespan through repair, replacement and product as a service models.

4 Enable

Direct financial support | Partnership frameworks | Fiscal frameworks Regulation | Legislation

- Support new partnership frameworks for industry in the region.
- Direct some of the local government funding to support the opportunities.
- Actively leverage existing state funding supporting the circular economy or advocate for additional funding.
- Advocate with state and federal government regulatory changes to incentivize circular economy and remove barriers in organics, construction and consumer goods and manufacturing sectors.

Adapted from Circle Economy – Urban Policy Framework

Recommendations: improve overtime the collection, quality, accuracy and granularity of data to close the gap

The circular scan employed the highest quality data available. However, several gaps were identified, as well as areas where data quality or collection could be improved. These are described in detail below along with recommendations for how this could be achieved.

Gap: Industrial material streams

- While the types of industries in the Loddon Mallee region are well-understood, there is little visibility surrounding the types, destinations and volumes of materials entering and leaving these industries.
- There is an opportunity here to develop data collection systems to improve understanding of these flows, with the aim of identifying circular economy solutions – particularly on the output side.
- One approach might be to link the data collection with the existing waste collection systems. This would involve coordinating with waste contractors to collect data on waste movements including material type, volume and destination.
- This information could remain confidential but give councils an understanding on where industrial waste is moving.

Data improvement: Agricultural flows

- The data used in the circular scan for the agricultural crop residues and produce waste was highly detailed in terms of location and crop type. However, the data was collected using surveys, which introduces limitations when surveys are not returned. There is also an added level of uncertainty when inferring amounts of crop residues and produce waste when only produce yield is available.
- The current understanding of agricultural flows could be improved within the region. Agriculture is currently undergoing a data revolution with requirements and technology to report production and on-farm parameters. Collaboration with the Grains Research & Development Corporation to extend data collection to include secondary products, residues and waste could improve both the overall measure of available organic flows but also help characterise the timing and locations of these materials.

Data improvement: Carbon abatement of opportunities

- Where possible, approximate carbon abatement of each circular economy opportunity was estimated, with the aim of providing a picture of how they compare to each other in terms of their potential environmental benefits.
- Calculations were primarily based on data available through LCA databases and scientific literature. For the opportunities chosen for future development, it is recommended to conduct a more detailed assessment of benefits, ideally using primary data from existing case studies.

Appendix A
material flow data - attached

Appendix B

assumptions for carbon abatement modelling

Appendix B – assumptions for carbon abatement modelling

Silage plastic recycling	Wheat straw into building materials	Insect protein	Glass crushing	Upcycling food waste	Anaerobic digestion
• Assumed 60-70% of silage plastics currently being burnt • Assumed 1000t annual total (expert consultation) • Assumed burning 1kg plastics results in 3 kg CO_2e (ALCAS, 2022) • Assumed 250km transport additional transport needed • Silage plastic recycling assumed to have similar savings to polyethylene recycling, which saves 1.37kg CO2e per kg plastic recycled (Ecoinvent, n.d.)	• Assumed all available wheat straw is processed into building materials. • 527,000 tonnes of wheat straw available, based on circular scan results. This accounts for required amount of stubble to be left on farm to maintain soil quality – straw only harvested for yields above 1.33 t/ha (Flower et al., 2020). • Compression of wheat straw = 22MJ/t (average from Ibrahim, 2019) (ALCAS, 2022 used for electricity impacts) • Assumed additional 60km of transport is required • Assumed plasterboard is offset • 1kg plasterboard (10mm) = 0.64kg CO_2e emissions (ALCAS, 2022) • *Note that this value is an upper limit of the potential benefits. While building panels have been modelled as an example product, there is unlikely to be enough market demand to utilise all wheat straw for these panels. Utilising the straw for further products such as packaging could expand the applications and access a greater portion of the straw. For an idea of scale, the current production of wheat straw panels could be increased over 30 times with the available wheat straw in the region. As shown by the results, accessing the available straw to products could have a significant environmental benefit*	• Impacts of insect protein production from literature (Salomone et al., 2016) • Assumed food waste obtained from commercial sources (hospitality and institutions) and from manufacturing • Assumed food waste into insect protein is avoided from landfill. • Assumed wheat grain is avoided by using insect protein in animal feed. Amount determined by relative protein content • Assumed wheat footprint of 0.3 kgCO2 per kg wheat (ALCAS, 2022) • Total available food waste from commercial sources is modelled as 16,000 t apportioned by population from National Food Waste Baseline (ARCADIS, 2019) • Total available food waste from manufacturing is modelled as 54,000 t apportioned by size of food production sector from National Food Waste Baseline (ARCADIS, 2019)	• Input: 9.9kt/year glass from domestic recycling bins • Assess three scenarios: 1. Glass taken to Melbourne and used in roads 2. Glass used in local roads 3. Glass taken to Melbourne and recycled back into packaging glass • Assumed mining for gravel and sand is avoided for glass input to roads • Assumed 25km transport from quarries to Melbourne • Assumed 200km transport from quarries to Loddon-Mallee • Assumed 200km transport from Loddon Mallee to Melbourne for use in Melbourne roads • Assumed no additional transport needed for use in local roads • For conversion to packaging glass in Melbourne: assumed 200km additional transport; assumed packaging glass production is offset	• Assumed average dry matter content of fruit and vegetables is 10% • Assumed additional 100km of transport required • Energy requirements for drying sliced produce = 14.6MJ/kg water (average from Nwakuba et al., 2016) • Two electricity sources considered: Victorian grid electricity and solar PV (ALCAS, 2022) • Assumed upcycling farm food waste avoids shallow burying of produce on-farm • Assume 61,000t of upcycled on-farm produce waste (from circular scan results, excluding sugar cane, grains, olives and grapes as these are not considered suitable feedstock) • Assumed production of vegetables is avoided, tomato production used as average to represent mix	• Calculation considers pig slurry liquid only • Assume one facility, with annual capacity of 20,000t slurry input • Using calculator from PlanET (PlanET, 2023) • Assumed 4% dry matter (Casey et al., 2017) • 1t = 32kWh electricity produced • Assumed average Victorian electricity is avoided (ALCAS, 2022 used for impact of Victorian grid electricity)
2,800 tonnes CO_2e **avoided**	330,000 tonnes CO_2e **avoided**	65,000 tonnes CO_2e **avoided**	1. Input to Melbourne roads: 125 tonnes CO_2e **produced** 2. Input to local roads: 245 tonnes CO_2e **avoided** 3. Recycling to packaging glass: 4,970 tonnes CO_2e **avoided**	1. With Victorian grid electricity: 200,000 tonnes CO_2e eq **produced** 2. With solar PV: 9,700 tonnes CO_2e eq **avoided**	650 tonnes CO_2e **avoided**

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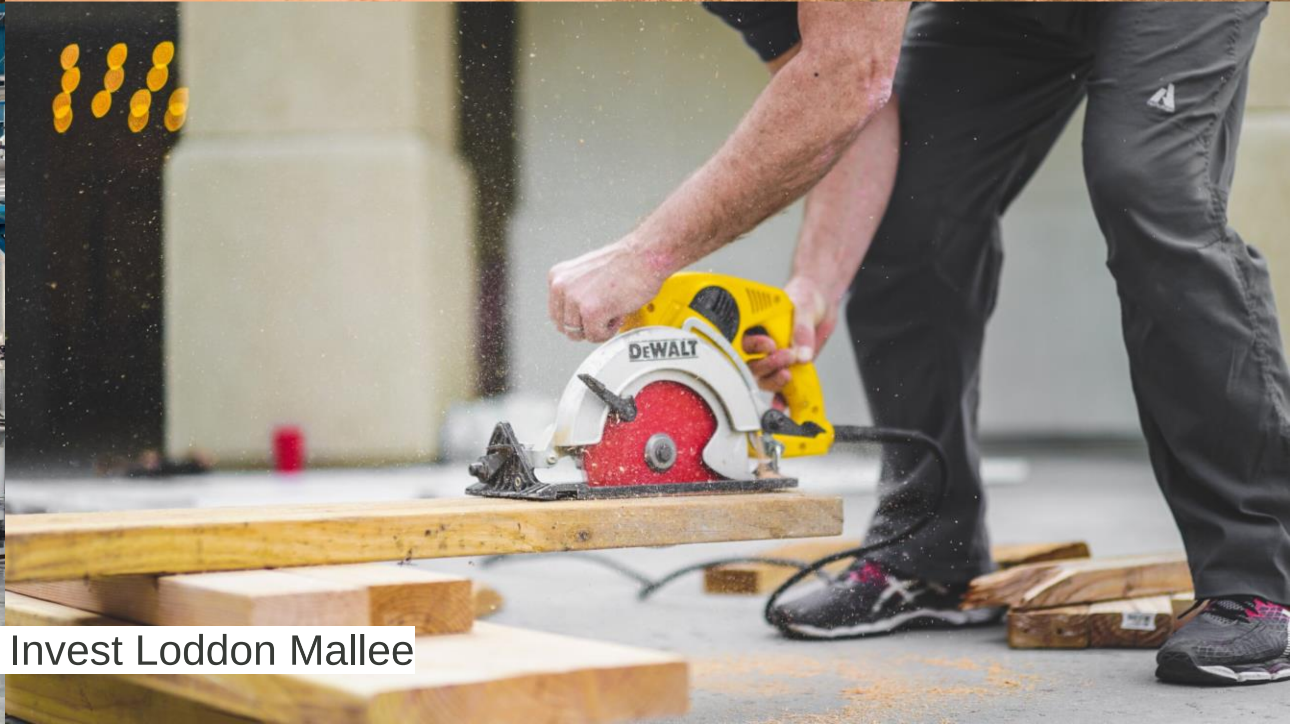

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